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ABSTRACT

One of a series of training manuals prepared for enlisted personnel in the Navy and Naval Reserve, this self-study unit relates directly to the occupational qualifications of the Aviation Support Equipment Technician M rating. Contents include a 15-chapter text followed by a subject index, qualifications for advancement, and the associated nonresident career course (fourteen reading assignments and technical questions based on the 15 chapters). Chapter headings are (1) Aviation Support Equipment Technician M Rating, (2) Tools and Lifting Devices, (3) Aviation Support Equipment, (4) Physics, (5) Publications, Maintenance Information Automated Retrieval System (MIARS), and Drawings, (6) Reciprocating Combustion Engines, (7) Reciprocating Gasoline Engines, (8) Diesel Engines, (9) Chassis Systems, (10) Power Trains, (11) Hardware, Fuels, Lubricants, and Hydraulic Fluids, (12) Gas Turbine Compressors, (13) Air Conditioners, (14) Preservation, and (15) Environmental Pollution Control. The appendixes include information on the metric system and a glossary of terms. (HD)

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AVIATION
SUPPORT EQUIPMENT TECHNICIAN M 3 & 2

NAVAL EDUCATION AND TRAINING COMMAND

RATE TRAINING MANUAL
AND NONRESIDENT CAREER COURSE

NAVEDTRA 10315-B

CE007624

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PREFACE

The ultimate purpose of training Naval personnel is to produce a combatant Navy which can ensure victory at sea. A Consequence of the quality of training given them is their superior state of readiness. Its result is a victorious Navy.

This Rate Training Manual and Nonresident Career Course (RTM/NRCC) form a self-study package that will enable ambitious Aviation Support Equipment Technician M to help themselves fulfill the requirements of their rating.

Designed for individual study and not formal classroom instruction, the RTM provides subject matter that relates directly to the occupational qualifications of the Aviation Support Equipment Technician M rating. The NRCC provides the usual way of satisfying the requirements for completing the RTM. The set of assignments in the NRCC includes learning objectives and supporting items designed to lead students through the RTM.

This Rate Training Manual and Nonresident Career Course were prepared by the Naval Education and Training Program Development Center, Pensacola, Florida, for the Chief of Naval Education and Training. Technical assistance was provided by the Aviation Support Equipment Technician School, Memphis, Tennessee and NAMTD 3032, Jacksonville, Florida.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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CHAPTER 1

AVIATION SUPPORT EQUIPMENT TECHNICIAN M RATING

This Rate Training Manual is designed as a self-study text for use by those personnel of the Navy and Naval Reserve who are preparing to meet the professional (technical) qualifications for advancement to Petty Officer Third Class and Petty Officer Second Class in the Aviation Support Equipment Technician M (ASM) rating. A second purpose of this manual is the improvement of job skills. This purpose is achieved through use of the manual as a study aid in conjunction with on-the-job training.

Minimum professional qualifications for advancement in all ratings are listed in the Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards, NAVPERS 18068 (Series). Formerly designated as the Manual of Qualifications for Advancement, NAVPERS 18068 is often referred to as the "Quals" Manual.

The occupational standards upon which this Rate Training Manual is based are those appearing in Change C of NAVPERS 18068. It should be kept in mind that any changes in the qualifications occurring after the (C) revision of the "Quals" Manual may not be reflected in the information presented in this training manual.

This chapter provides information on the enlisted rating structure, the ASM rating, requirements and procedures for advancement, and references that will help you in working for advancement and in performing your duties as an ASM. Also included is information on how to make the best use of Rate Training Manuals. It is therefore strongly recommended that you study this chapter carefully before beginning intensive study of the remainder of the manual.

ENLISTED RATING STRUCTURE

The present enlisted rating structure consists of general ratings and service ratings.

General ratings identify broad occupational fields of related duties and functions. Some general ratings include service ratings; others do not. Both Regular Navy and Naval Reserve personnel may hold general ratings.

The general rating provides the primary means of identifying billet requirements and personnel qualifications; it is established or disestablished by the Secretary of the Navy; and it is provided a distinctive rating badge. The general rate is the pay grade level within the general rating.

Service ratings identify subdivisions or specialties within a general rating which require related patterns of aptitudes and qualifications, and which provide paths of advancement for career development. Although service ratings can exist at any petty officer level, they are most common at the PO3 and PO2 levels. Both Regular Navy and Naval Reserve personnel may hold service ratings.

The Navy Enlisted Classification Coding System (NEC) has been set up to help the Navy match the right person with the right job. By identifying billets that require special skills, and by identifying people who have or can develop these special skills, the NEC system provides the Navy with a means of getting maximum usefulness from its manpower. Any person who gains the qualifications associated with one of the special skills is given a code number, called his NEC.

AVIATION SUPPORT EQUIPMENT TECHNICIAN (AS) RATING

The AS rating is divided into three service ratings at pay grades E-4 and E-5. The service ratings are ASE (Electrical), ASH (Hydraulics and Structures), and ASM (Mechanical). The general rating, AS, applies at pay grades E-6 through E-9.

Figure 1-1 illustrates all paths of advancement for an Airman Recruit to Master Chief Aviation Support Equipment Technician, Chief Warrant Officer (W-4), and to Limited Duty Officer. Shaded areas indicate career stages where qualified enlisted personnel may advance to Warrant Officer (W-1), and where selected Warrant Officers may advance to Limited Duty Officer. Personnel in enlisted rates and warrant ranks not in shaded areas may advance only as indicated by the arrows.

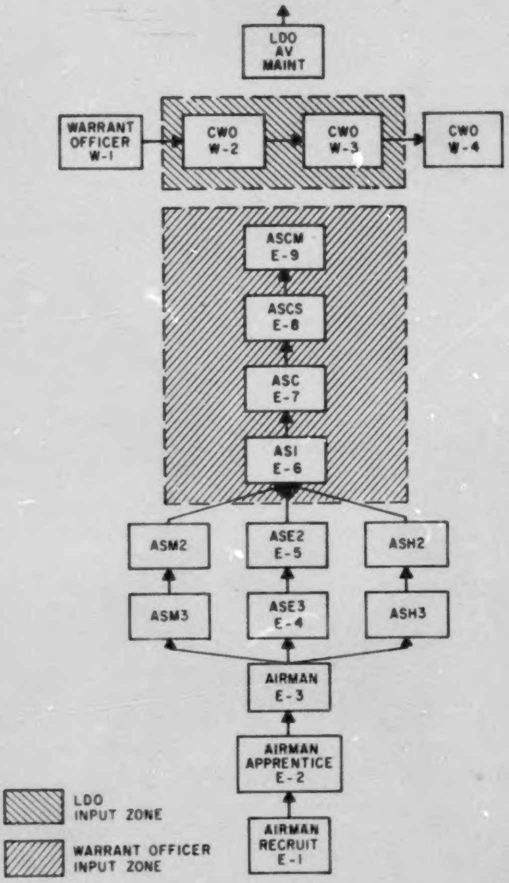

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Figure 1-1.—Paths of advancement.

Figure 1-2(A) illustrates the active duty advancement requirements from E-1 through E-9. Figure 1-2(B) illustrates the inactive duty advancement requirements.

The Aviation Support Equipment Technician M (Mechanical) services, tests, and performs maintenance and repair of gasoline and diesel engines in mobile and self-propelled aviation support equipment and associated automotive systems, including fuel systems, transmissions, differentials, and steering systems; maintains gas turbine compressor units and air conditioning systems used in servicing aircraft; maintains and operates gas turbine compressor unit test stands; and performs periodic maintenance inspections of aviation support equipment.

As an ASM3 or ASM2, your assignment possibilities cover a wide range of duties and responsibilities. Your specific duties will depend to a great extent upon the type of organization to which you are attached. A greater number of ASMs are assigned to activities which perform intermediate level maintenance. These billets exist aboard aircraft carriers and naval air stations. In each instance, the ASM will most likely be attached to the support equipment division of the Aircraft Intermediate Maintenance Department (AIMD).

The ASM may also be assigned to a unit that performs organizational maintenance. The unit may be permanently attached to a particular naval air station, or may use a certain naval air station as a home port and alternate between the station and a ship or between the home port and another land base or bases.

Instructor duty is available to the ASM2 and in special instances may be available to the ASM3. Instructor billets are available in the AS school of NAS Memphis, Millington, Tennessee, in the Naval Air Maintenance Training Group (NAMTG) with headquarters at Memphis, and with the Chief of Naval Education and Training Support in Pensacola, Florida.

REQUIREMENTS *	E1 to E2	E2 to E3	# E3 to E4	# E4 to E5	E5 to E6	† E6 to E7	† E7 to E8	† E8 to E9
SERVICE	4 mos. service— or completion of Recruit Training.	8 mos. as E-2.	6 mos. as E-3 2 years time in service.	12 mos. as E-4. 3 years time in service.	24 mos. as E-5. 6 years time in service.	36 mos. as E6. 9 years time in service	36 mos. as E-7. 8 of 12 years time in service must be enlisted.	36 mos. as E-8. 10 of 15 years time in service must be enlisted.
SCHOOL	Recruit Training. (C.O. may advance up to 10% of graduating class.)	▨	Class A for PR3, DT3, PT3, AME 3, HM 3, PN 3, FTB 3, MT 3,	▨	▨	Navy School for AGC, MUC, MNC.††		
PRACTICAL FACTORS	Locally prepared check-offs.	Record of Practical Factors, NAVEDTRA 1414/1, must be completed for E-3 and all PO advancements.						
PERFORMANCE TEST	▨	▨	Specified ratings must complete applicable performance tests before taking examinations.				▨	▨
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement multiple.					
EXAMINATIONS **	Locally prepared tests.	See below.	Navywide examinations required for all PO advancements.			Navywide selection board.		
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)	▨	Required for E-3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed. See NAVEDTRA 10052 (current edition).					Nonresident career courses and recommended reading. See NAVEDTRA 10052 (current edition).	
AUTHORIZATION	Commanding Officer		NAVEDTRA PRODEVCEN					

* All advancements require commanding officer's recommendation.

† 3 years obligated service required for E-7, E-8, and E-9.

# Military leadership exam required for E-4 and E-5.

** For E-2 to E-3, NAVEDTRA PRODEVCEN exams or locally prepared tests may be used.

†† Waived for qualified EOD personnel.

Figure 1-2(A).—Active duty advancement requirements.

REQUIREMENTS *	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7	E8	E9
TOTAL TIME IN GRADE	4 mos.	8 mos.	6 mos.	12 mos.	24 mos.	36 mos. with total 8 yrs service	36 mos. with total 11 yrs service	24 mos. with total 13 yrs service
TOTAL TRAINING DUTY IN GRADE†	14 days	14 days	14 days	14 days	28 days	42 days	42 days	28 days
PERFORMANCE TESTS	▨		Specified ratings must complete applicable performance tests before taking examination.					
DRILL PARTICIPATION	Satisfactory participation as a member of a drill unit in accordance with BUPERSINST 5400.42 series.							
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)	Record of Practical Factors, NavEdTra 1414/1, must be completed for all advancements.							
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)	Completion of applicable course or courses must be entered in service record.							
EXAMINATION	Standard Exam		Standard Exam required for all PO advancements. Also pass Military Leadership Exam for E-4 and E-5.				Standard Exam. Selection Board.	
AUTHORIZATION	Commanding Officer		NAVEDTRA PRODEVCEN					

* Recommendation by commanding officer required for all advancements.
† Active duty periods may be substituted for training duty.

Figure 1-2(B).—Inactive duty advancement requirements.

Instructor billets are normally filled on a voluntary basis. Detailed information concerning assignment to instructor duty is contained in the Enlisted Transfer Manual, NAVPERS 15909 (Series).

Since you have been in pay grade E-3 or E-4 for some time, you realize that more leadership is required of the higher rates. Not only are you required to have superior knowledge, but you are also required to have the ability to handle personnel. This ability increases in importance as you advance through the various rates as a petty officer.

In General Order No. 21, the Secretary of the Navy outlined some of the most important aspects of naval leadership. By naval leadership is meant the art of accomplishing the Navy's mission through people. It is the sum of those qualities of intellect, of human understanding, and of moral character that enables a person to inspire and to manage a group of people successfully. Effective leadership, therefore, is based on personal example, good management practices, and moral responsibility. The term leadership includes all three of these elements.

The current Navy Leadership Program is designed to keep the spirit of General Order No. 21 ever before you. If the threefold objective is carried out effectively in every command, the program will make you a better leader of men in your present billet and in your future assignments. As you advance up the ladder of leadership, your worth to the Navy will be judged increasingly on the basis of the amount of efficient work you obtain from your subordinates rather than how much of the actual work you do yourself.

For information on the practical application of leadership and supervision, study *Military Requirements for Petty Officer 3 & 2,* NAVEDTRA 10056 (Series).

ADVANCEMENT

Both you and the Navy benefit from your advancement. You get more pay, and your assignments are more interesting and challenging. You can enjoy getting ahead in the Navy on your own efforts. Highly trained personnel are essential to the functioning of the Navy. By advancement, you increase your value to the Navy in two ways: First, you become more valuable as a technical specialist in your own rating; and second, you become more valuable as a person who can train others, and thus make far-reaching contributions to the entire Navy.

The advancement system includes those requirements that must be met before you may be considered for advancement and those factors that actually determine whether or not you will be advanced. In this part of this chapter information is presented to help you prepare and become qualified for advancement and to inform you of the method used for selecting those who will be advanced.

BUPERS Notice 1418 will give you information on advancement examinations. Have your Educational Services Officer or your Training Petty Officer explain parts of these notices you do not understand.

PREPARING FOR ADVANCEMENT

What must you do to prepare for advancement? You must study the qualifications for advancement, work on the practical factors, study the required Rate Training Manuals and other material that is required. You will need to be familiar with the following:

1. Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards, NAVPERS 18068 (Series).
2. Record of Practical Factors, NAVEDTRA 1414/1.
3. Bibliography for Advancement Study, NAVEDTRA 10052 (Series).
4. Applicable Rate Training Manuals and their companion Nonresident Career Courses.
5. Examination for advancement procedures.

Collectively, these documents make up an integrated training package tied together by the occupational standards. The following paragraphs describe these materials and give some information on how each one is related to the others.

"Quals" Manual

The Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards, NAVPERS 18068 (Series), gives the minimum requirements for advancement. This manual is usually called the "Quals" Manual, and the qualifications themselves are called occupational standards. The "Quals" Manual can be found in your Educational Services Office or may be obtained from your Training Petty Officer.

Occupational standards are expressed as task statements only, unlike the advancement qualifications which contain practical factors and knowledge factors. The approved concept for occupational standards is that they define what enlisted personnel must do in their rate or rating and that the knowledges required to perform a task are inherent to the proper performance of the task. The practical and knowledge factors presently in the "Quals" Manual will be replaced with occupational standards.

Occupational standards are identified by a five-digit number of which the first two digits identify the standard topic title and the remaining three digits identify the specific task statement.

NOTE: As stated previously, the occupational standards upon which this Rate Training Manual is based are those appearing in NAVPERS 18068-C, which is titled Manual of Qualifications for Advancement. Therefore, the material is based on practical and knowledge factors which are identified by alphanumeric codes. For example, G2.03, "Use of publications relating to the inspection, servicing, and maintenance of aircraft," is a knowledge factor under this system. In the new NAVPERS 18068 (Series), Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards, the above occupational standard will probably appear as 46091, "Use publications and instructions to perform inspections, servicing, and maintenance of aircraft." Any reference to qualifications or occupational standards in this manual pertains to the old system.

The standards are of two general types: military requirements, and professional (or technical) requirements.

Military requirements apply to all ratings rather than to any one particular rating. Military requirements for advancement to third class and second class petty officer rates deal with military conduct, naval organization, military justice, security, watch standing, and other subjects which are required of petty officers in all other ratings.

Professional requirements are technical or professional in nature and are directly related to the work of each rating. Both the military requirements and the professional requirements are divided into subject matter groups; then within each subject matter group, they are divided into specific task statements.

The occupational standards for ASM are listed in this manual following the index. Study these standards and the military requirements carefully. The majority of the questions on your advancement examination will try to determine your understanding of the requirements reflected in the occupational standards. If you are working for advancement to second class, remember that you may be examined on third class occupational standards as well as on second class occupational standards.

It is essential that the occupational standards reflect current requirements of fleet and shore operations, and that new fleetwide technical, operational, and procedural developments be included. For these reasons, the occupational standards are continually under evaluation. Although there is an established schedule for revisions to the occupational standards for each rating, urgent changes to the occupational standards may be made at any time. These revisions are issued in the form of changes to the "Quals" Manual. Therefore, never trust any set of occupational standards until you have checked the change number against an up-to-date copy of the "Quals" Manual. Be sure you have the latest revision.

Record of Practical Factors, NAVEDTRA 1414/1

Before you can take the Navy-wide examination for advancement, there must be an entry in your service record to show that you have qualified in the practical factors of both the military requirements and the professional standards. A special form known as the Record of Practical Factors, NAVEDTRA 1414/1 (plus the abbreviation of the appropriate rating), is used to keep a record of your practical factor qualifications. The form lists all practical factors, both military and professional. As you demonstrate your ability to perform each practical factor, appropriate entries are made in the DATE and INITIALS columns.

Changes are made periodically to the "Quals" Manual, and revised forms of NAVEDTRA 1414/1 are provided when necessary. Extra space is allowed on the Record of Practical Factors for entering additional practical factors as they are published in changes. The Record of Practical Factors also provides space for recording demonstrated proficiency in skills which are within the general scope of the rate but which are not identified as minimum qualifications for advancement.

If you are transferred before you qualify in all practical factors, NAVEDTRA 1414/1 should be forwarded with your service record to your next duty station. You can save yourself a lot of trouble by making sure that this form is actually inserted in your service record before you are transferred. If the form is not in your service record, you will be required to start over again and requalify in the practical factors which have already been checked off.

A second copy of the Record of Practical Factors should be made available to each man in pay grades E-2 through E-8 for his personal record and guidance.

The importance of NAVEDTRA 1414/1 must be strongly emphasized. It serves as a record to indicate to the petty officers and officers supervising your work that you have demonstrated proficiency in the performance of the indicated practical factors and is part of the criteria utilized by your commanding officer when he considers recommending you for advancement. In addition, the proficient demonstration of the applicable practical factors listed on this form can aid you in preparing for the examination for advancement. Remember that the knowledge aspects of the practical factors are covered in the examinations for advancement. Certain knowledge is required to demonstrate these practical factors and additional knowledge can be acquired during the demonstration. Background knowledge is required to perform a certain job. In other words, the knowledge required for a certain rating depends upon the jobs (practical factors) that must be performed by personnel of that rating. Therefore, the knowledge required to proficiently demonstrate these practical factors will definitely aid you in preparing for the examination for advancement.

Personnel Qualification Standards

Personnel Qualification Standards (PQS), described in OPNAV Instruction 3500.34, are presently being utilized to provide guidelines in preparing for advancement and qualification to operate specific equipment and systems. They are designed to support the advancement requirements as stated in the "Quals" Manual.

The occupational standards and Record of Practical Factors are stated in broad terms. Each PQS is much more specific in its questions that lead to qualification. It provides an analysis of specific equipment and duties, assignments, or responsibilities which an individual or group of individuals (within the same rating) may be called upon to carry out. In other words, each PQS provides an analysis of the complete knowledge and skills required of that rating tied to a specific weapon system (aircraft and/or individual systems or components).

Each qualification standard has four main subdivisions in addition to an introduction and a glossary of PQS terms. They are as follows:

100 Series–Theory
200 Series–System
300 Series–Watchstations (duties, assignments or responsibilities)
400 Series–Qualification cards

The introduction explains the complete use of the qualification standard in terms of what it will mean to the user as well as how to use it.

The Theory (100 Series) section specifies the theory background required as a prerequisite to the commencement of study in the specific equipment or system for which the PQS was written. These fundamentals are normally taught in the formal schools (Preparatory, Fundamentals, and Class A) phase of an individual's training. However, if the individual has not been to school, the requirements are outlined and referenced to provide guidelines for a self-study program.

The Systems (200 Series) section breaks down the equipment or systems being studied into functional sections. PQS items are essentially questions asked in clear, concise statement (question) form and arranged in a standard format. The answers to the questions must be extracted from the various maintenance manuals covering the equipment or systems for which the PQS was written. This section asks the user to explain the function of the system, to draw a simplified version of the system from memory, and to use this drawn schematic or the schematic provided in the maintenance manual while studying the system or equipment. Emphasis is given to such areas as maintenance management procedures, components, component parts, principles of operation, system interrelations, numerical values considered necessary to operation and maintenance, and safety precautions.

The Watchstation (300 Series) section includes questions regarding the procedures the individual must know to operate and maintain the equipment or system. A study of the items in the 200 series section provides the individual with the required information concerning what the system or equipment does, how it does it, and other pertinent aspects of operation. In the 300 series section, the questions advance the qualification process by requiring answers or demonstrations of ability to put this knowledge to use or to cope with maintenance of the system or equipment. Areas covered include normal operation; abnormal or emergency operation; emergency procedures which could limit damage and/or casualties associated with a particular operation; operations that occur too infrequently to be considered mandatory performance items; and maintenance procedures/instructions such as checks, tests, repair, replacement, etc.

The 400 Series section consists of the qualification cards. These cards are the accounting documents utilized to record the individual's satisfactory completion of items necessary for becoming qualified in duties assigned. Where the individual starts in completing a standard will depend on his assignment within an activity. The complete PQS should be given to the individual being qualified so that he can utilize it at every opportunity to become fully qualified in all areas of his rating and the equipment or system for which the PQS was written. Upon transfer to a different activity, each individual must requalify. The answers to the questions asked in the qualification standards may be given orally or in writing to the supervisor, the branch or division officer, and maintenance officer as required to certify proper qualification. The completion of part or all of the PQS provides a basis for the supervising petty officer and officer to certify completion of Practical Factors for Advancement.

Bibliography for Advancement Study

The Bibliography for Advancement Study, NAVEDTRA 10052 (Series), is a very important publication for anyone preparing for advancement. This bibliography lists required and recommended Rate Training Manuals and other reference material to be used by personnel working for advancement. NAVEDTRA 10052 is revised and issued once each year by the Naval Education and Training Support Command. Each revised edition is identified by a letter following the NAVEDTRA number. When using this publication, be sure that you have the most recent edition.

If extensive changes in qualifications occur between the annual revisions of NAVEDTRA 10052, a supplementary list of study material may be issued in the form of a BUPERS Notice. When you are preparing for advancement, check with your Educational Services Officer or your Training Petty Officer to see whether changes have been made in the qualifications. If changes have been made, see if a BUPERS Notice has been issued to supplement NAVEDTRA 10052.

The required and recommended references are listed by rate level in NAVEDTRA 10052. If you are working for advancement to third class, study the material that is listed for third class. If you are working for advancement to second class, study the material that is listed for second class, and remember that you will also be examined on the references listed at the third class level.

NOTE: Personnel preparing for advancement will be examined on the TOTAL BIBLIOGRAPHY. Publications listed for a given paygrade frequently make specific reference to other publications. These specific referrals are part of the TOTAL BIBLIOGRAPHY. Emphasis must be placed on the military/technical TOTAL BIBLIOGRAPHY for each paygrade; examinations are based on it.

In using NAVEDTRA 10052, you will notice that some Rate Training Manuals are marked with an asterisk (*). Any manual marked in this way is MANDATORY–that is, it must be completed at the indicated rate level before you are eligible to take the Navy-wide examination for advancement. Each mandatory manual may be completed by passing the appropriate Nonresident Career Course that is based on the mandatory training manual; passing locally prepared tests based on the information given in the training manual; or in some cases, successfully completing an appropriate Class A School.

Do not overlook the front section of NAVEDTRA 10052 which lists the required and recommended references relating to the military standards/requirements for advancement. For example, all personnel must complete the Rate Training Manual, *Military Requirements for Petty Officer 3 & 2,* NAVPERS 10056 (Series), for the appropriate rate level before they can be eligible to advance.

The references in NAVEDTRA 10052 which are recommended, but not mandatory, should also be studied carefully. All references listed in NAVEDTRA 10052 may be used as source material for the written examinations at the appropriate rate levels.

Rate Training Manuals

There are two general types of Rate Training Manuals. Rating manuals (such as this one) are prepared for most enlisted rates, giving information that is directly related to the professional qualifications. Basic manuals give information that applies to more than one rate and rating. *Basic Electricity,* NAVPERS 10086 (Series), is an example of a basic manual because many ratings use it for reference.

Rate Training Manuals are revised from time to time to keep them up to date technically. The revision of a Rate Training Manual is identified by a letter following the NAVEDTRA number. You can tell whether any particular copy of a Rate Training Manual is the latest edition by checking the NAVEDTRA number and the letter following this number in the most recent edition of *List of Training Manuals and Correspondence Courses,* NAVEDTRA 10061 (Series). NAVEDTRA 10061 is a catalog that lists current training manuals and correspondence courses; you will find this catalog useful in planning your study program.

Rate Training Manuals are designed to help you prepare for advancement. The following suggestions may help you to make the best use of this manual and other Navy training publications when you are preparing for advancement.

1. Study the military requirements and the professional qualifications for your rate before you study the training manual, and refer to the occupational standards frequently as you study. Remember, you are studying the training manual in order to meet these occupational standards.
2. Set up a regular study plan. If possible, schedule your studying for a time of day when you will not have too many interruptions or distractions.
3. Before you begin to study any part of the training manual intensively, become familiar with the entire manual. Read the preface and the table of contents. Check through the index. Look at the appendixes. Thumb through the manual without any particular plan, looking at the illustrations and reading bits here and there as you see things that interest you.

4. Look at the training manual in more detail to see how it is organized. Look at the table of contents again. Then, chapter by chapter, read the introduction, the headings, and the subheadings. This will give you a clear picture of the scope and content of the manual. As you look through the manual in this way, ask yourself some questions: What do I need to learn about this? What do I already know about this? How is this information related to information given in other chapters? How is this information related to the occupational standards?

5. When you have a general idea of what is in the training manual and how it is organized, fill in the details by intensive study. In each study period, try to cover a complete unit—it may be a chapter, a section of a chapter, or a subsection. If you know the subject well, or if the material is easy, you can cover quite a lot at one time. Difficult or unfamiliar material will require more study time.

6. In studying any one unit—chapter, section, or subsection—write down the questions that occur to you. Many people find it helpful to make a written outline of the unit as they study, or at least to write down the most important ideas.

7. As you study, relate the information in the training manual to the knowledge you already have. When you read about a process, a skill, or a situation, try to see how this information ties in with your own past experience.

8. When you have finished studying a unit, take time out to see what you have learned. Look back over your notes and questions. Maybe some of your questions have been answered; but perhaps you still have some that are not answered. Without referring to the training manual, write down the main ideas that you have learned from studying this unit. Do not quote the manual. If you cannot give these ideas in your own words, the chances are that you have not really mastered the information.

9. Use Nonresident Career Courses (NRCC) whenever you can. These courses are based on Rate Training Manuals or on other appropriate texts. As mentioned before, completion of a mandatory Rate Training Manual can be accomplished by passing a Nonresident Career Course based on the Rate Training Manual. You will probably find it helpful to take other courses in addition to those based on mandatory training manuals. Taking a Nonresident Career Course helps you to master the information given in the training manual, helps you to see how much you have learned, and can serve for refresher study.

10. Think of your future as you study Rate Training Manuals. You are working for advancement to third class or second class right now, but someday you will be working toward higher rates. Anything extra that you can learn now will help you.

Nonresident Career Course

The Nonresident Career Course (NRCC), formerly called Enlisted Correspondence Course, for this Rate Training Manual (RTM) has been included at the back of the manual. Its purpose is to assist you in the training necessary to fulfill your job and advancement requirements; it will be of benefit to you when preparing for the Navy-wide Advancement Examinations; and it reflects the more important information in the manual.

Included in the course are learning objectives which state knowledges you will acquire by choosing the correct answer to each question or by restudying until you can choose the correct answer. The questions are teaching tools that point out important things in the Rate Training Manual. The Nonresident Career Course is an important part of the training package presented within these covers.

The answer sheets to the NRCC, referred to as IKOR (immediate knowledge of results) sheets, are a separate package and are not included with this Rate Training Manual. A separate errata sheet may be included with this training package. If present, it will inform you of any changes in the text of the RTM or the NRCC. For complete instructions on this NRCC, read the preliminary pages thoroughly before you proceed with the course.

QUALIFYING FOR ADVANCEMENT

In general, to qualify (be considered) for advancement, you must:

1. Have a certain amount of time in your present pay grade.
2. Demonstrate knowledge of material in your mandatory Rate Training Manual by making a suitable score on your command's test on the manual, by successfully completing the NRCC on the manual, or, in some cases, by graduating from an appropriate Navy school.
3. Demonstrate your ability to perform all the practical requirements for advancement by completing the *Record of Practical Factors,* NAVEDTRA 1414/1.
4. Be recommended by your commanding officer, after the petty officers and officers supervising your work have indicated that they consider you capable of performing the duties of the next higher rate by recommending you for advancement to the commanding officer.
5. For petty officer third and second candidates only, demonstrate knowledge of military subjects by passing the MILITARY/LEADERSHIP examination based on the military occupational standards for advancement (from NAVPERS 18068 (Series)).

In addition to these requirements, to qualify for advancement you must demonstrate an understanding of the technical aspects of your rate by passing a Navy-wide advancement examination based on the occupational standards applicable to your rate (from NAVPERS 18068 (Series), those occupational standards listed at or below your rate level).

If you meet all of the above requirements satisfactorily, you are in a group from which advancements will be made.

WHO WILL BE ADVANCED?

Advancement is not automatic. Meeting all of the requirements makes you eligible but does not guarantee your advancement. Some of the factors that determine which persons, out of all of those qualified, will actually be advanced in rate are the score made on the advancement examination, the length of time in service, the performance marks earned, and the number of vacancies being filled in a given rate.

If the number of vacancies in a given rate exceed the number of qualified personnel, then all of those qualified will be advanced. More often, the number of qualified people exceeds the vacancies. When this happens, the Navy has devised a procedure for advancing those who are best qualified. This procedure is based on combining the three following personnel evaluation systems:

1. Merit rating system (Annual evaluation and C.O. recommendation)
2. Personnel testing system (Advancement examination score—with some credit for passing previous advancement exams)
3. Longevity (seniority) system (Time in rate and time in service)

Simply, credit is given for how much the individual has achieved in the areas of performance, advancement test, and seniority. A composite, known as the final multiple score, is generated from these three factors. All of the candidates who have PASSED the examination from a given advancement population are then placed on one list. Based on the final multiple score, the person with the highest multiple score is ranked first, and so on, down to the person with the lowest multiple score. For candidates for E-4, E-5, and E-6, advancement authorizations are then issued, beginning at the top of the list, for the number of persons needed to fill the existing vacancies.

Candidates for E-7 whose final multiple scores are high enough will be designated PASS SELBD ELIG (Pass Selection Board Eligible). This means that their names will be placed before the Chief Petty Officer Selection Board, a BUPERS board charged with considering all so-designated eligible candidates for advancement to CPO. Advancement authorizations for those being advanced to CPO are issued by this board.

Who, then, are the individuals who are advanced? Basically, they are the ones who achieved the most in preparing for advancement. They were not content to just qualify; they went the extra mile in their training, and through that training and their work experience they developed greater skills, learned more, and accepted more responsibility.

While it cannot guarantee that any one person will be advanced, the advancement system does guarantee that all persons within a particular rate will compete equally for the vacancies that exist and that the best qualified persons will be advanced.

EXAMINATION PROCEDURES

Examinations are given to candidates for advancement to E-4 through E-6 in February and August each year. E-7 through E-9 exams are given only once a year. The time and place of the examinations will be published in the Plan of the Day and in your station or unit paper. You must appear at the designated time and place in the uniform of the day and with your ID card. If you are to take the exam for ASM3 no other person taking that exam will sit near you. This helps ensure that all taking the exam have an equal chance. The examiner or a proctor will read to you the instructions to be followed. Be sure you listen to and follow these instructions carefully.

You will have three hours. Each question on the exam will have four possible answers from which to choose the correct one. Read each question carefully and all of the possible answers. If you know the correct answer, mark your answer sheet. If you do not know the answer, go to the next question. This will ensure that you have time to answer all the questions to which you know the answers in the time allotted. Each time you mark the answer sheet make your mark in the same number as the question.

After you have gone through the exam and answered all the questions to which you know the answers, go through the exam again and answer the questions that you can limit to two probably correct answers. Then you can spend the remaining time considering the questions about which you have the least knowledge and checking the questions and answers you have already completed. When the allotted time has passed, the proctor will collect the examination booklets and the answer sheets.

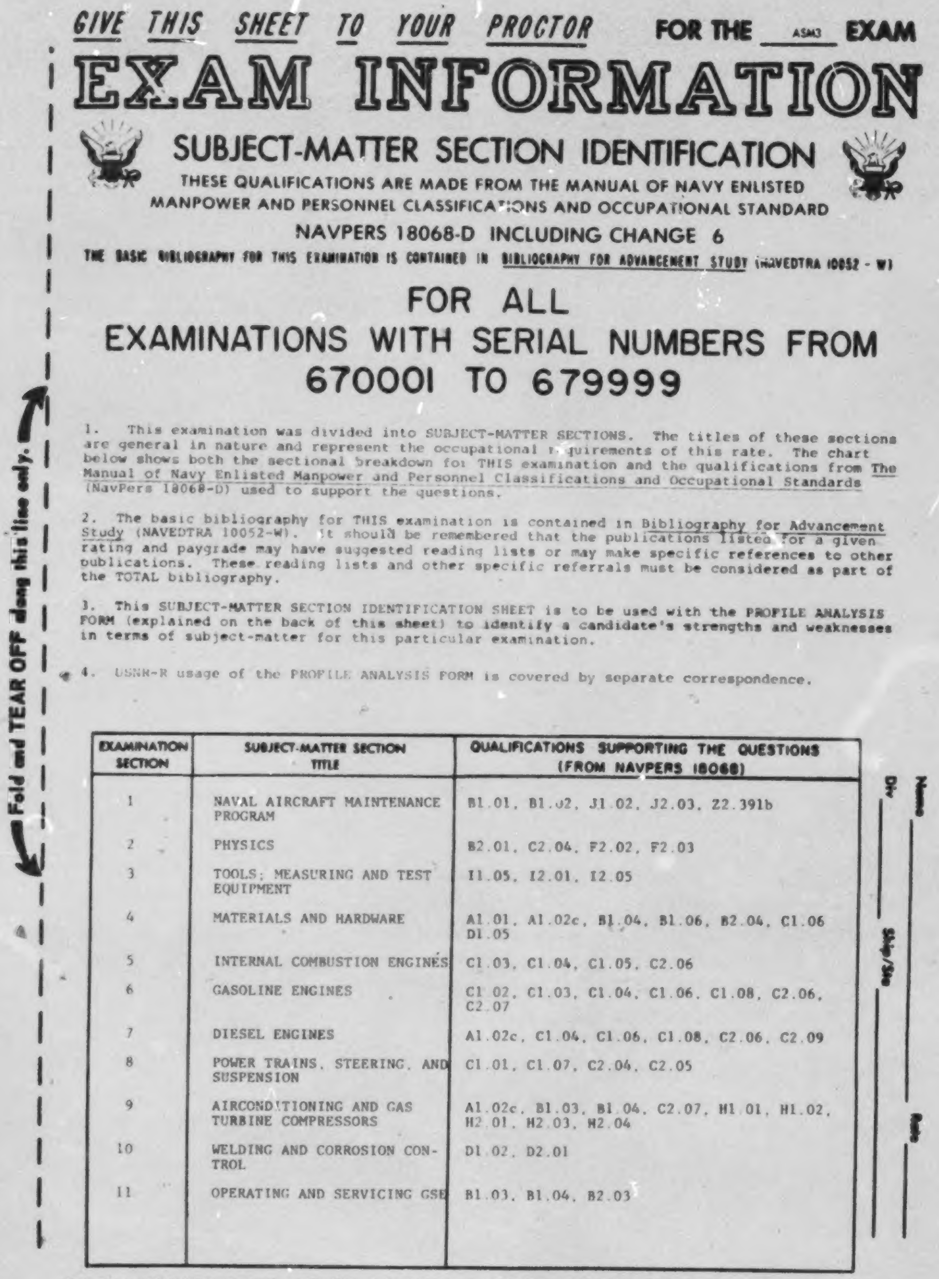
SUBJECT-MATTER SECTION IDENTIFICATION SHEET

The Subject-Matter Section Identification Sheet (fig. 1-3) is a tear-out sheet included in your Navy-wide advancement examination booklet. It is to be detached from the booklet upon completion of the examination and given to the exam proctor. This sheet indicates the subject-matter sections of the examination which represent the occupational requirements for the rate. The occupational standards used to support the examination questions are also indicated for each subject-matter section. This sheet will be retained by the Educational Services Officer (ESO) for purposes of command review upon receipt of the Profile Analysis Form. Both of these forms will be made available to you for your review at a date subsequent to the date of examination.

PROFILE ANALYSIS FORM

The Profile Analysis Form (fig. 1-4) is provided to all candidates two or three months after competing in the Navy-wide advancement examination. Normally, this form will be made available to you by your ESO with the Subject-Matter Section Identification Sheet, previously discussed. The Profile Analysis Form is to be used in conjunction with the Subject-Matter Section Identification Sheet to indicate your strengths and weaknesses for the particular examination in which you competed.

The Profile Analysis Form (refer to fig. 1-4) indicates the candidate's relative standing in Section 1 of the examination as being "A.. (Average-middle). Section 1, as indicated on the Subject-Matter Section Identification Sheet, dealt with questions relating to the "Naval Aviation Maintenance Program". You can, therefore, conclude that your standing was average, in comparison with the rest of the candidates, for Section 1 of the examination, the "Naval Aviation Maintenance Program". The occupational standards used to support the



GIVE THIS SHEET TO YOUR PROCTOR **FOR THE** ASM3 **EXAM**

EXAM INFORMATION

SUBJECT-MATTER SECTION IDENTIFICATION

THESE QUALIFICATIONS ARE MADE FROM THE MANUAL OF NAVY ENLISTED MANPOWER AND PERSONNEL CLASSIFICATIONS AND OCCUPATIONAL STANDARD

NAVPERS 18068-D INCLUDING CHANGE 6

THE BASIC BIBLIOGRAPHY FOR THIS EXAMINATION IS CONTAINED IN BIBLIOGRAPHY FOR ADVANCEMENT STUDY (NAVEDTRA 10052 - W)

FOR ALL EXAMINATIONS WITH SERIAL NUMBERS FROM 670001 TO 679999

1. This examination was divided into SUBJECT-MATTER SECTIONS. The titles of these sections are general in nature and represent the occupational requirements of this rate. The chart below shows both the sectional breakdown for THIS examination and the qualifications from The Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards (NavPers 18068-D) used to support the questions.

2. The basic bibliography for THIS examination is contained in Bibliography for Advancement Study (NAVEDTRA 10052-W). It should be remembered that the publications listed for a given rating and paygrade may have suggested reading lists or may make specific references to other publications. These reading lists and other specific referrals must be considered as part of the TOTAL bibliography.

3. This SUBJECT-MATTER SECTION IDENTIFICATION SHEET is to be used with the PROFILE ANALYSIS FORM (explained on the back of this sheet) to identify a candidate's strengths and weaknesses in terms of subject-matter for this particular examination.

4. USNR-R usage of the PROFILE ANALYSIS FORM is covered by separate correspondence.

EXAMINATION SECTION	SUBJECT-MATTER SECTION TITLE	QUALIFICATIONS SUPPORTING THE QUESTIONS (FROM NAVPERS 18068)
1	NAVAL AIRCRAFT MAINTENANCE PROGRAM	B1.01, B1.02, J1.02, J2.03, Z2.391b
2	PHYSICS	B2.01, C2.04, F2.02, F2.03
3	TOOLS; MEASURING AND TEST EQUIPMENT	I1.05, I2.01, I2.05
4	MATERIALS AND HARDWARE	A1.01, A1.02c, B1.04, B1.06, B2.04, C1.06 D1.05
5	INTERNAL COMBUSTION ENGINES	C1.03, C1.04, C1.05, C2.06
6	GASOLINE ENGINES	C1.02, C1.03, C1.04, C1.06, C1.08, C2.06, C2.07
7	DIESEL ENGINES	A1.02c, C1.04, C1.06, C1.08, C2.06, C2.09
8	POWER TRAINS, STEERING, AND SUSPENSION	C1.01, C1.07, C2.04, C2.05
9	AIRCONDITIONING AND GAS TURBINE COMPRESSORS	A1.02c, B1.03, B1.04, C2.07, H1.01, H1.02, H2.01, H2.03, H2.04
10	WELDING AND CORROSION CONTROL	D1.02, D2.01
11	OPERATING AND SERVICING GSE	B1.03, B1.04, B2.03

Name ____________

Div ____________

Ship/Sta ____________

Rate ____________

Fold and TEAR OFF along this line only.

THE BASIC BIBLIOGRAPHY FOR THIS EXAMINATION IS CONTAINED IN BIBLIOGRAPHY FOR ADVANCEMENT STUDY (NAVEDTRA 10052-W)

THIS SHEET MUST BE USED WITH MANUAL OF NAVY ENLISTED MANPOWER AND PERSONNEL CLASSIFICATIONS AND OCCUPATIONAL STANDARDS (NAVPERS 18068-D)

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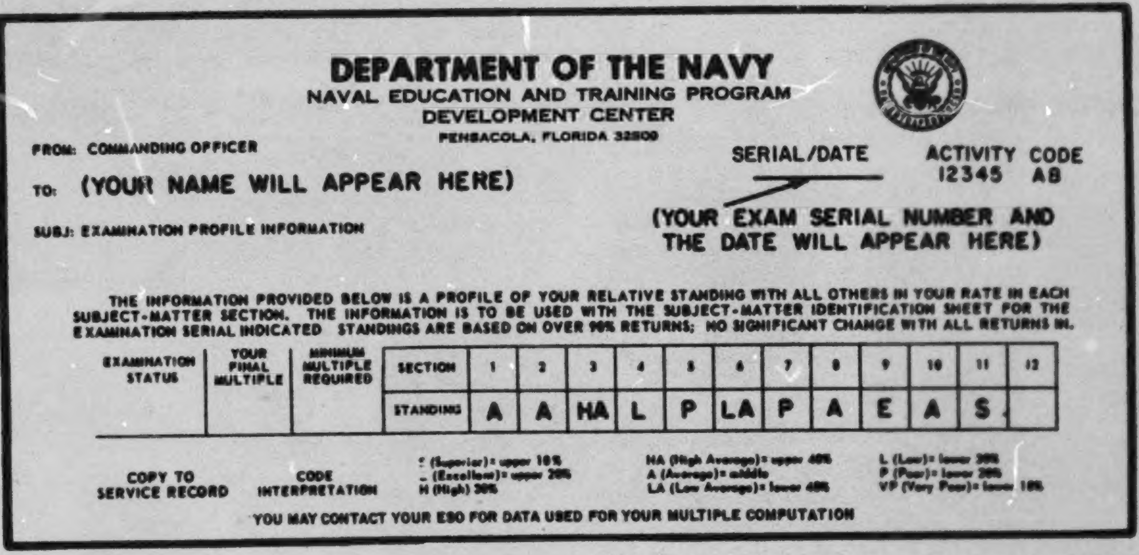
Figure 1-3.—Subject-Matter Section Identification Sheet.



DEPARTMENT OF THE NAVY
NAVAL EDUCATION AND TRAINING PROGRAM
DEVELOPMENT CENTER
PENSACOLA, FLORIDA 32509

FROM: COMMANDING OFFICER

TO: (YOUR NAME WILL APPEAR HERE)

SUBJ: EXAMINATION PROFILE INFORMATION

SERIAL/DATE

ACTIVITY CODE
12345 AB

(YOUR EXAM SERIAL NUMBER AND THE DATE WILL APPEAR HERE)

THE INFORMATION PROVIDED BELOW IS A PROFILE OF YOUR RELATIVE STANDING WITH ALL OTHERS IN YOUR RATE IN EACH SUBJECT-MATTER SECTION. THE INFORMATION IS TO BE USED WITH THE SUBJECT-MATTER IDENTIFICATION SHEET FOR THE EXAMINATION SERIAL INDICATED STANDINGS ARE BASED ON OVER 90% RETURNS; NO SIGNIFICANT CHANGE WITH ALL RETURNS IN.

EXAMINATION STATUS	YOUR FINAL MULTIPLE	MINIMUM MULTIPLE REQUIRED	SECTION	1	2	3	4	5	6	7	8	9	10	11	12
			STANDING	A	A	HA	L	P	LA	P	A	E	A	S	

COPY TO SERVICE RECORD

CODE INTERPRETATION

S (Superior)= upper 10%
E (Excellent)= upper 20%
H (High) 30%
HA (High Average)= upper 40%
A (Average)= middle
LA (Low Average)= lower 40%
L (Low)= lower 30%
P (Poor)= lower 20%
VP (Very Poor)= lower 10%

YOU MAY CONTACT YOUR ESO FOR DATA USED FOR YOUR MULTIPLE COMPUTATION

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Figure 1-4.–Profile Analysis Form.

questions on the "Naval Aviation Maintenance Program" were B1.02, J1.02, J2.03, Z2.39lb. The same procedure should be followed for the remaining sections of the examination.

By the use of these two forms you will be able to determine those areas where additional study could assist you in future examinations.

SOURCES OF INFORMATION

One of the most useful things you can learn about a subject is how to find out more about it. No single publication can give you all the information you need to perform the duties of your rating. You should learn where to look for accurate, authoritative, up-to-date information on all subjects related to the military requirements for advancement and the professional standards of your rating.

Some of the publications described in this manual are subject to change or revision from time to time–some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure that you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made. Studying canceled or obsolete information will not help you perform efficiently or to advance; it is likely to be a waste of time, and may even be seriously misleading.

TRAINING FILMS

Training films available to naval personnel are a valuable source of supplementary information on many technical subjects. Training films are listed in the United States Navy Film Catalog, NAVAIR 10-1-777 (formerly NAVWEPS 10-1-777), published in 1969. Copies of this catalog may be ordered in accordance with the Navy Stock List of Forms and Publications, NAVSUP 2002. Monthly supplements to the Film Catalog are distributed to catalog holders. Check with your Training Petty Officer for the location of the nearest Film Catalog.

When selecting a film, note its date of issue listed in the Film Catalog. As you know, procedures sometimes change rapidly; thus, some films become obsolete rapidly. If a film is obsolete only in part, it may still be of some use.

EDUCATIONAL SERVICES OFFICER

One of the officers at your ship or station has been designated as the Educational Services Officer (ESO). The office of the ESO will be your point of contact for many of your educational and training needs. When you need a Rate Training Manual, a Basic Manual, or wish to order a Nonresident Career Course, this office will accommodate you.

The ESO office is provided each year with the QUAL/BIB sheets for each rating. These sheets indicate the latest occupational standards and bibliography for your rating and are for your personal use in preparing for advancement.

NOTE: You should check with your ESO to make certain that there have been no changes to the occupational standards as indicated by the latest change to NAVPERS 18068, or to the bibliography as indicated in the latest revision to NAVEDTRA 10052.

The ESO office also provides numerous other services of which you should avail yourself. It is to the advantage of each person in the Navy to utilize to the fullest extent the services provided by the ESO.

TRAINING PETTY OFFICER

A petty officer in your unit (squadron, station, division, department, or ship) has been designated the Training Petty Officer. He usually organizes and supervises the training for advancement in rating for the unit, while the petty officer under whom you work organizes and supervises the on-the-job training. A part of the Training Petty Officer's duties is to arrange for instructors and meeting places and set the time for lectures. He may have manuals you need to study for the advancement examination; if he does not have the material available, he will know where you can get it. He should be a big help to you in your program to become qualified for the next higher rate and well prepared for the advancement examination.

CHAPTER 2

TOOLS AND LIFTING DEVICES

The ASM3 and ASM2 must have a thorough knowledge of tools of his trade to enable him to increase his performance and the quality of his products. Using this knowledge and applying it in the right direction will aid in increasing his efficiency and support equipment's operational availability. One of the most important abilities that a mechanic can have is the ability to use the tools which are required to complete any given task in a skilled and technical manner.

A mechanic is known by the tools he keeps. The use of tools may vary; but safety, good care, and the proper stowage of tools never vary. In this section, the various tools that the ASM uses in the course of his duties are briefly described. *Tools and Their Uses,* NavPers 10085 (Series), also contains a description of most of the tools used by the ASM, together with detailed instructions for using them. The material given in this section is intended to supplement, rather than repeat, the information given in *Tools and Their Uses.*

PROCUREMENT OF TOOLS

Generally, each activity will have a centrally located toolroom which procures tools for the activity as a whole. This allows for better usage and accountability of the equipment. An activity's allotted amount of handtools is in accordance with an allowance which is established by the NAVAIR 00-35 QG16 Allowance Lists. This series of allowance lists includes all of the accountable and consumable general support equipment which is required for the maintenance and operation of all types of aircraft at the Intermediate and Organizational levels of maintenance.

CUSTODY

When it becomes necessary or desirable for an ASM to have a toolbox assigned to him on a custody basis, the division chief will notify the toolroom personnel to issue an ASM toolbox to the designated person. Normally, the central toolroom will have a locally prepared toolbox inventory form. This form will be applicable to the particular equipment and maintenance level to be supported. They will issue the toolbox in accordance with this inventory form, making two copies—one (master copy) to be held by the central toolroom, and one to be placed in the toolbox. The ASM should use this copy to inventory his toolbox after completion of his assigned work to insure that all of his tools have been placed back in his toolbox.

NOTE: Reinventory of tools taken to the job is a MUST to eliminate the possibility of damage to the equipment due to foreign objects left adrift within or around the equipment.

INVENTORY

The ASM who has custody of a toolbox must prevent the loss of tools through neglect or misuse. Although handtools are normally classed as consumable items, they are very expensive and must be paid for when lost or carelessly damaged. One method of preventing loss of tools is a thorough inventory after each job assignment. Usually, the activity will have a local instruction concerning the inventory interval and method of reporting of lost or damaged tools.

NOTE: Broken or damaged tools can damage equipment hardware and parts. They can also cause personal injury to the worker or others.

At the periodic inventory, which is normally performed by central toolroom personnel, all broken or missing tools should be replaced. Nonproductive time between job assignments provides ample time for further inspection and upkeep of toolboxes.

In addition to the tools normally issued with the toolbox, there are many special tools an ASM3 and ASM2 will come in contact with and use. Later in this chapter we will discuss just a few of these tools. Special tools are normally kept in the central toolroom or in the repair shop and signed out on an as-needed basis. These checked out tools are returned to the toolroom as soon as the ASM has completed his work assignment. (Tools should be returned on the same day as checked out.)

Each activity has an allowance of special tools which they may have on custody. Often the allowance for an item is only one, which means positive control must be exercised.

HANDTOOLS

Most of the handtools normally issued to the ASM are covered in this section. They are classified as cutting tools, turning tools, striking tools, holding tools, and miscellaneous handtools.

TOOLBOX

The toolbox shown in figure 2-1 is the type normally used by the ASM to stow his tools. The current set of tools is likely to include only those needed often in doing his assigned work. The tools should be organized in the box by type and size, and those needed often placed where they can be reached most easily. Tools should be kept straight, and extras such as parts, pieces of "junk," etc., kept out of the box.

A padlock is issued with each toolbox. The toolbox should be kept locked and stored in the designated area.

CUTTING TOOLS

Diagonal Pliers

Diagonal cutting pliers are an important tool for the ASM. They are used for cutting small wire and cotter pins etc. Since they are small they should not be used to cut large wire or heavy material because the pliers will be damaged by such use and then not be effective to cut what they were designed to cut. They can also be used to remove small cotter pins where a new pin is to be used when the work is finished. This is done by gripping the pin near the hinge of the pliers and lifting up on the handles, releasing the pin, getting a new grip, and repeating until the pin is removed.

The inner jaw surface is a diagonal straight cutting edge offset approximately 15 degrees which permits cutting objects flush with the surface. The diagonal cutting pliers are not designed to hold objects since to use enough force to hold an object the pliers will cut or deform the object. The sizes of the diagonal pliers are indicated by the overall length of the pliers.

Files

The ASM's toolbox should include an assortment of files. They are used for cutting, smoothing, or removing small amounts of metal,

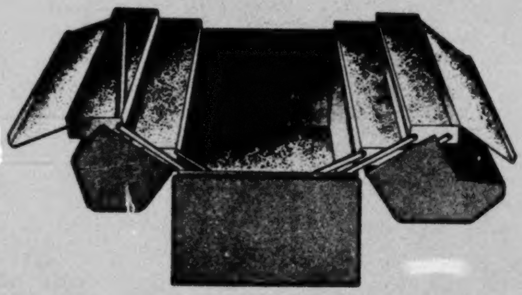

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Figure 2-1.—Standard Navy toolbox.

and are made of hardened high-carbon-content steel. Adequate coverage on the selection, care, and use of files is contained in *Tools and Their Uses,* NAVPERS 10085 (Series) and is therefore not repeated here.

Hacksaws

A hacksaw is used primarily for sawing metal. There are two different kinds of hacksaw frames; one has a pistol-grip handle; the other has a straight handle. Most hacksaws are adjustable to take blades of various lengths. *Tools and Their Uses,* NAVPERS 10085 (Series) describes and illustrates the principles involved in selecting the most suitable blade for different types of work and gives coverage on the use and care of hacksaws.

TURNING TOOLS

Socket Wrench

The socket wrench is one of the most versatile wrenches in the toolbox. Basically, it consists of a handle and a socket-type wrench which can be attached to that handle. A complete socket wrench set consists of several types of handles along with bar extensions, universals, adapters, and a variety of sockets. (See fig. 2-2.)

SOCKETS.–A socket has an opening cut in one end to fit a drive on a detachable handle. The handle drive is usually square. In the other end of the socket is a 6-point or 12-point opening very much like the opening in the box end wrench. The 12-point socket needs to be swung only half as far as the 6-point socket before it may be lifted and fitted on the nut for a new grip. It can therefore be used in closer quarters where there is less room to move the handle. Most sockets have 12 points. However, the 6-point socket has its use with nuts made of stainless steel, which are made of harder metal than that of the wrench. Extensive use of a 12-point socket on such nuts or bolts would cause excessive wear on the 12-points so that the socket might fail to hold. By contrast, because of the greater holding surface, a 6-point socket holds the stainless steel nut better, offering less chance for wear of the wrench.

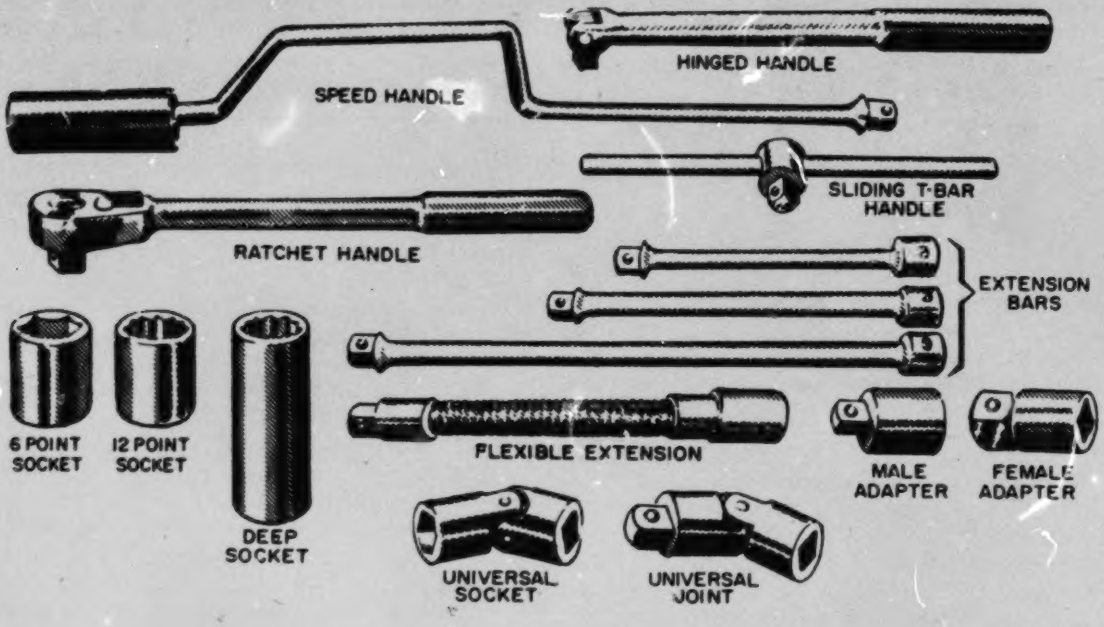
Sockets are classified for size according to two factors. One is the drive size or square opening which fits on the square drive of the handle. The other is the size of the opening in the opposite end, which fits the nut or bolt. The standard mechanic toolbox is usually outfitted with sockets that have 1/4- and 3/8-inch-square drivers. The openings that fit onto the bolt or nut are graduated in 1/16-inch sizes. Sockets are also made in deep lengths to fit over spark plugs and long bolt ends.

There are four types of handles used with these sockets. (See fig. 2-2.) Each type has special advantages, and the good mechanic chooses the one best suited to the job at hand. The square driving lug on the socket wrench handles has a spring-loaded ball that fits into a recess in the socket receptacle and holds the assembly together. This mated ball-recess feature prevents the parts of the wrench from falling apart during normal usage, but a slight pull disassembles any wrench connection.

RATCHET HANDLE.–The ratchet handle has a reversing lever which operates a pawl (or dog) inside the head of the tool. Pulling the handle in one direction causes the pawl to engage in the ratchet teeth and to turn the socket. Moving in the opposite direction causes the pawl to slide over the teeth, permitting the handle to back up without moving the socket. This allows rapid turning of the nut or bolt after each partial turn of the handle. With the reversing lever in one position, the handle can be used for tightening. In the other position, it can be used for loosening.

HINGED HANDLE.–The hinged handle is also very convenient. To loosen a tight nut, swing the handle at right angles to the socket. This gives the greatest possible leverage. After loosening the nut to the point where it turns easily, move the handle into the vertical position and then turn the handle with the fingers.

SLIDING T-BAR HANDLE.–While using the sliding bar on T-handle, the head can be


HINGED HANDLE
SPEED HANDLE
SLIDING T-BAR HANDLE
RATCHET HANDLE
EXTENSION BARS
6 POINT SOCKET
12 POINT SOCKET
DEEP SOCKET
FLEXIBLE EXTENSION
MALE ADAPTER
FEMALE ADAPTER
UNIVERSAL SOCKET
UNIVERSAL JOINT

213.26.1

Figure 2-2.–Typical socket wrench set.

positioned at either the end or the center of the sliding bar. Select the position which is needed for the job at hand.

SPEED HANDLE.–The speed handle is worked like the woodworker's brace. After the nuts are first loosened with the sliding bar handle or the ratchet handle, the speed handle will help remove the nuts in a hurry. In many instances the speed handle is not strong enough to be used for breaking loose or tightening. The speed socket wrench should be used carefully, to avoid damaging the nut threads.

ACCESSORIES.–To complete the socket wrench set, there are several accessory items. Extension bars of different lengths are made to extend the handles to any length needed. A universal joint allows the nut be turned with the wrench handle at an angle. A universal socket is also available, and universal socket joints, bar extensions, and universal sockets in combination with appropriate handles makes it possible to form a variety of tools that will reach otherwise inaccessible nuts and bolts.

Another accessory item which comes in handy is an adapter which allows the ASM to use a handle having one size drive with a socket having a different size drive. For example, a 3/8- by 1/4-inch adapter would make it possible to turn all 1/4-inch square drive sockets with any 3/8-inch square drive handle.

There are special sockets which are used to adapt various types of screwdriver bits to a speed handle (fig. 2-3). This socket type screwdriver is used to remove recessed head screws from access panels on equipment.

Combination Wrenches

The ASM's toolbox should contain a complete set of combination wrenches. The

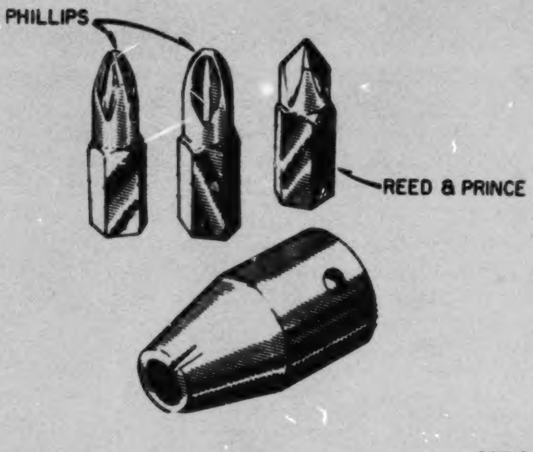


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Figure 2-3.—Screwdriver adapter.

combination wrench (fig. 2-4) has an open-end wrench on one end and a box-end (of the same size) on the other end. For speed and light stress operations, use the open-end; then switch to the box-end for safety under stress. For ease of explanation, each end of the wrench will be discussed separately.

The box-end fits completely around the nut or bolthead. The box-end is usually constructed with 12 points. The advantage of the 12-point construction is that the wrench will operate between obstructions where space for the swing angle is limited. A very short swing of the handle will turn the nut far enough to allow the wrench to be lifted and the next set of points to be fitted to the corners of the nut. It is possible to use this wrench in places where the swing angle is limited to as little as 30 degrees.

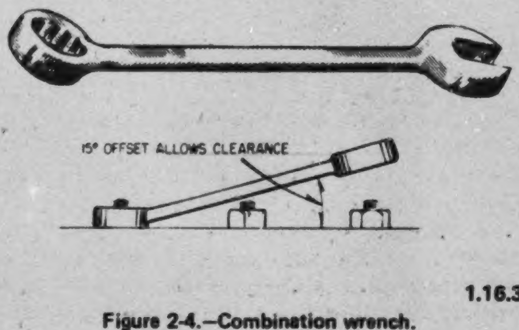
The box-end portion of the wrench is designed with an offset in the handle. Notice in figure 2-4 how the 15 degrees offset will allow clearance over nearby parts. One of the best features of the box-end is that there is little or no chance of a wrench slipping off the nut or bolt. However, there is the disadvantage of slow work with the box-end of the combination wrench. Each time the wrench is backed off, the wrench has to be lifted up and refitted to the head of the work. Therefore, to save time, use the nonslip box-end of the wrench to break loose tight bolts or to snug up work after the bolt has been seated with a faster type wrench which might slip under stress.

The jaws of the open-end portion of the combination wrench are machined at 15 degrees from parallel in respect to the centerline of the handle. This permits the use of the wrench in places where there is room to make only a part of a complete turn of a nut or bolt. If the wrench is turned over after the first swing, it will fit on the same flats and turn the nut farther. After two swings on the wrench, the nut is turned far enough so that a new set of flats are in position for the wrench.

The open end of the combination wrench may be used on tubing nuts and in cramped places too small for a socket or box end to be slipped over the nut or bolthead. When using any open-end type wrench, always insure that the wrench fits the nut or bolthead, and pull on the wrench—never push. Pushing a wrench is dangerous. The threads could break loose unexpectedly and cause damage to adjacent equipment or injury to the person using the wrench.

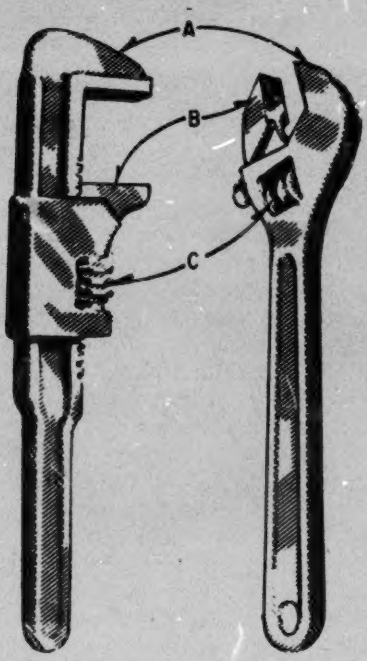
Adjustable Wrenches

Adjustable wrenches are not intended to replace open-end wrenches, but they are useful in working in restricted areas. In addition, they can be adjusted to fit odd size nuts. However,



1.16.3

Figure 2-4.—Combination wrench.



213.26.3

Figure 2-5.–Adjustable wrenches.

adjustable wrenches are not intended for standard use but rather for emergency use. They were not built for use on extremely hard-to-turn items. As shown in figure 2-5, adjustable wrenches have a fixed jaw (A) and an adjustable jaw (B) which is adjusted by a thumbscrew (C). By turning the thumbscrew, the jaw opening may be adjusted to fit various sizes of nuts. The size of the wrenches ranges from 4 to 18 inches in length. The maximum jaw openings vary in direct proportion to the length of the handle.

Adjustable wrenches are often called "knuckle busters" because mechanics frequently suffer the consequences of improper usage of these tools.

There are four simple steps to follow in using these wrenches. First, choose one of the correct size, that is, do not pick a large 12-inch wrench and adjust the jaw for use on a 3/8-inch nut. This could result in a broken bolt and a bloody hand. Second, be sure the jaws of the correct size wrench are adjusted to fit snugly on the nut. Third, position the wrench around the nut until the nut is all the way into the throat of the jaws. If not used in this manner, the result is apt to be as bloody as before. Fourth, pull the handle toward the side having the adjustable jaw. This will prevent the adjustable jaw from springing open and slipping off the nut. If the location of the work will not allow all four steps to be followed when using an adjustable wrench, then select another type of wrench for the job.

Adjustable wrenches should be cleaned in a solvent, and a light oil applied to the thumbscrew and the sides of the adjustable jaw. They should also be inspected often for cracks which might result in failure of the wrench.

Screwdrivers

Two basic screwdriver blade types are used–the common blade for use on conventional slotted screws and a crosspoint blade for use on the recessed head Phillips or Reed and Prince type screws. Both types of screwdrivers are illustrated in figure 2-6. The common and crosspoint blade types are used in the design of various special screwdrivers, some of which are also shown in figure 2-6.

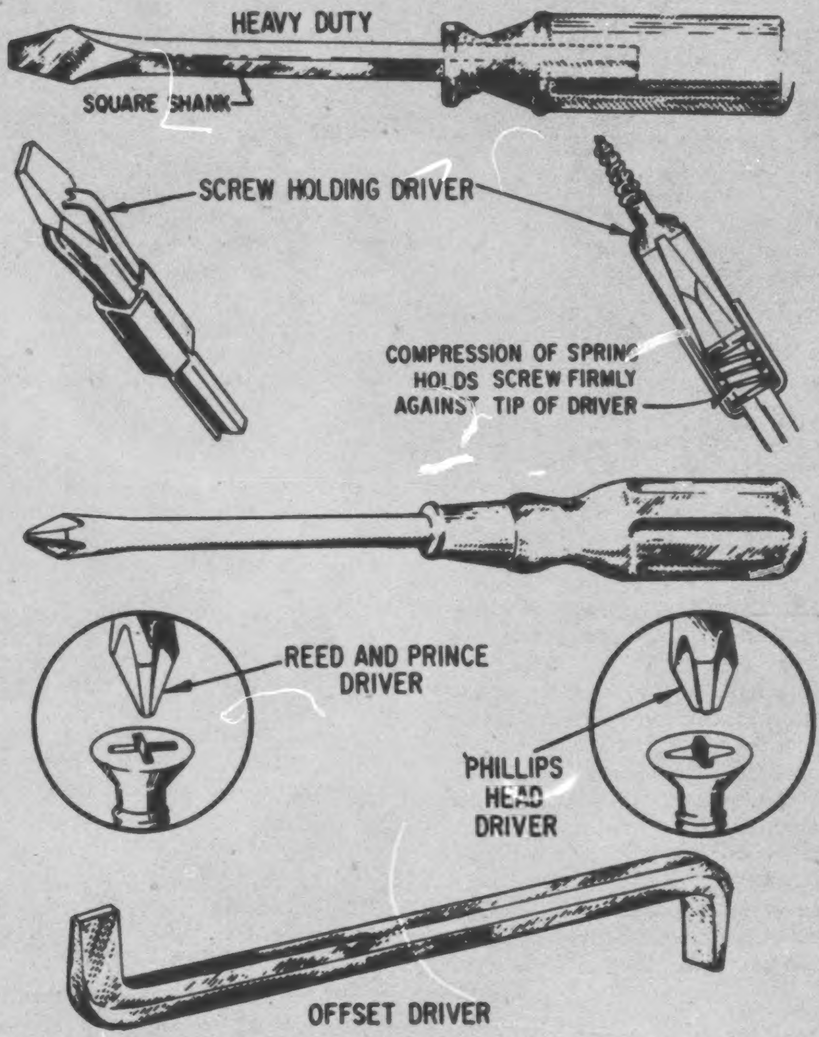
COMMON SCREWDRIVERS.–The combined length of the shank and blade identifies the size of common screwdrivers. They vary from 2 1/2 to 12 inches. The diameter of the shank and the width and thickness of the blade tip which fits the screw slot are in proportion to the length of the shank. The blade is hardened to prevent it from being damaged when it is used on screws. It can easily be chipped or blunted when used for other purposes. The blade of a poor quality screwdriver will sometimes become damaged even when being used properly.

A damaged common screwdriver may be repaired by dressing the blade if done correctly. This can be done by the following instructions:

1. Dress the sides with an emery wheel so that the blade is symmetrical in shape.

2. Square off the end with the wheel; check for squareness by resting the tip on the handle of a trysquare, and move the shank of the screwdriver close to the blade of the trysquare. If the blade of the trysquare and shank are parallel, the tip is square.

CROSSPOINT SCREWDRIVERS.–There are two types of crosspoint screwdrivers in common use–the Reed and Prince, and the Phillips. The Reed and Prince screwdrivers and Phillips screwdrivers are not interchangeable; therefore, always use Reed and Prince


HEAVY DUTY
SQUARE SHANK
SCREW HOLDING DRIVER
COMPRESSION OF SPRING HOLDS SCREW FIRMLY AGAINST TIP OF DRIVER
REED AND PRINCE DRIVER
PHILLIPS HEAD DRIVER
OFFSET DRIVER

227.1

Figure 2-6.–Typical screwdrivers.

screwdriver with Reed and Prince screws and a Phillips screwdriver with Phillips screws. The use of the wrong screwdriver will result in mutilation of the screwhead.

OFFSET SCREWDRIVERS.—An offset screwdriver (fig. 2-6) may be used where there is not sufficient vertical space for a standard screwdriver. Offset screwdrivers are constructed with one blade forged in line and another blade forged at right angles to the shank handle. Both blades are bent 90 degrees to the shank handle. By alternating ends, most screws can be seated or loosened even when the swinging space is very restricted. Offset screwdrivers are made for both standard and recessed head screws.

CAUTION: When using any type of screwdriver, do not hold the work in the hand. If the point slips, it can cause a bad cut. The ASM will always be safe when following this rule: Never get any part of the body in front of the screwdriver point. This is a good safety rule for any sharp-pointed tool. When removing a screw from an assembly that is not stationary, hold the work on a solid surface, in a vise, or with some other holding tool.

TORQUE TOOLS

Torque is the result of a force that produces rotation: force times distance equals the torque about a point (F x L = T). The force is the amount of pressure exerted on the handle of the torque wrench and is measured in weight units such as grams or ounces. The lever length is measured in units such as meters and inches. Torque is expressed in weight-length units such as gram-centimeters, ounce-inches, pound-feet, etc. Torque units may be changed to other torque units without changing their value. For example, ounce-inches can be converted to pound-inches by dividing by 16, the number of ounces in a pound. Table 2-1 is a torque conversion table.

Table 2-1.—Torque value conversion

Divide	By	To Obtain
Gram-centimeters	2.54	Gram-inches
Gram-centimeters	72	Ounce-inches
Ounce-inches	16	Pound-inches
Pound-inches	12	Pound-feet
Multiply	**By**	**To Obtain**
Gram-inches	2.54	Gram-centimeters
Ounce-inches	72	Gram-centimeters
Pound-inches	16	Ounce-inches
Pound-feet	12	Pound-inches

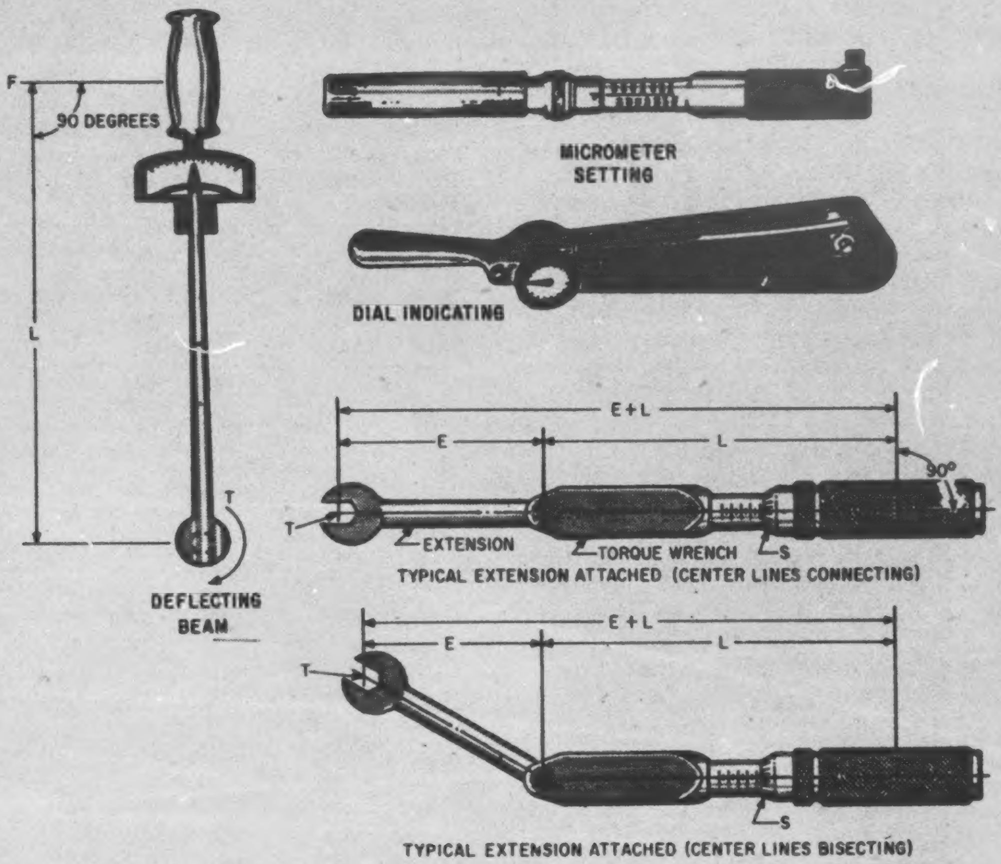
(1 inch = 2.54 Centimeters)
(1 ounce = 28.35 Grams)

Torque Wrenches

There are times when, for engineering reasons, a definite pressure must be applied to a nut, bolt, screw, or other fastener. In such cases a torque wrench must be used. The torque wrench is a precision tool consisting of a torque-indicating handle and appropriate adapter or attachments. It is used to measure the amount of turning or twisting force applied to a nut, bolt, or screw.

The three most commonly used torque wrenches are the Deflecting Beam, Dial Indicating, and Micrometer Setting types (fig. 2-7). When using the Deflecting Beam and the Dial Indicating torque wrenches, the torque is read visually on a dial or scale mounted on the handle of the wrench.

To use the Micrometer Setting type, unlock the grip and adjust the handle to the desired setting on the micrometer scale, then relock the grip. Install the required socket or adapter to the square drive of the handle. Place the wrench assembly on the nut or bolt and pull in a clockwise direction with a smooth steady motion. (A fast or jerky motion will result in an improperly torqued unit.) When the torque applied reaches the torque value indicated on the handle setting, the handle will automatically release or "break" and move freely for a short distance. The release and free travel is easily felt, so there is no doubt about when the torquing process is complete.


F
90 DEGREES
L
T
T
DEFLECTING BEAM
MICROMETER SETTING
DIAL INDICATING
E+L
E
L
90°
T
EXTENSION
TORQUE WRENCH
S
TYPICAL EXTENSION ATTACHED (CENTER LINES CONNECTING)
E+L
E
L
T
S
TYPICAL EXTENSION ATTACHED (CENTER LINES BISECTING)

195.8.1

Figure 2-7.—Torque wrenches.

To assure getting the correct amount of torque on the fasteners, all torque handles must be tested at least once a month, or more often if usage indicates it is necessary.

The following precautions should be observed when using torque wrenches:

1. Do not use the torque wrench as a hammer.

2. When using the Micrometer Setting type, do not move the setting handle below the lowest torque setting. However, it should be placed at its lowest setting prior to returning to storage.

3. Do not use the torque wrench to apply greater amounts of torque than its rated capacity.

4. Do not use the torque wrench to break loose bolts which have been previously tightened.

5. Never store a torque wrench in a toolbox or in an area where it may be damaged.

TORQUE VALUES.—Torquing can be described as the twisting stress that is applied to the fasteners to secure components together. These fasteners can be nuts, bolts, studs, clamps, Table 2-2.–Torque value in inch-pounds for standard nuts, bolts, and screws

Wrench size	Standard nuts, bolts, and screws		
	Bolt, stud, or screw size	Tensior type nuts AN310 and AN365	Shear type uts AN320 and AN364
1/4	4-48	4-5.5	2.5-3.5
5/16	6-40	7.5-11	4.5-6.5
11/32	8-36	12-15	7-9
3/8	10-32	20-25	12-15
7/16	1/4-28	50-70	30-40
1/2	5/16-24	100-140	60-85
9/16	3/8-24	160-190	95-110
5/8	7/16-20	450-500	270-300
3/4	1/2-20	480-690	290-410
7/8	9/16-18	800-1,000	480-600
15/16	5/8-18	1,100-1,300	660-780
1 1/16	3/4-16	2,300-2,500	1,300-1,500
1 1/4	7/8-14	2,500-3,000	1,500-1,800
1 7/16	1-14	3,700-5,500	2,200-3,300

NOTE: AN specification numbers may be superseded by MS specification numbers.

etc. Torque values for these fasteners are expressed in inch-pounds or foot-pounds. Unless otherwise stated, all torque values should be obtained with the manufacturer's recommended thread lubricant applied to the threads.

Torque values are usually listed in the appropriate section of the applicable Instructions Manual. However, in case there is no torque specified, the torque values in table 2-2 can be used as a guide in tightening nuts, bolts, and screws. Using the proper torque allows the structure to develop its design strength and greatly reduces the possibility of failure due to fatigue. One word of caution–never rely on memory for torque information, but look up the correct torque value each time it is needed. A nut or bolt that is not torqued to the proper value may cause damage to the component or equipment.

The proper procedure is to tighten at a uniformly increasing rate until the desired torque is obtained. In some cases, where gaskets or other parts cause a slow permanent set, the torque must be held at the desired value until the material is seated. When applying torque to a series of bolts on a flange or in an area, select a median value. If some bolts in a series are torqued to a minimum value and others to a maximum, force is concentrated on the tighter bolts and is not distributed evenly. Such unequal distribution of force may cause shearing or snapping of the bolts.

Torque wrench size must be considered when torquing. The torque wrenches are listed according to size and should be used within this recommended range. Use of larger wrenches which have too great a tolerance results in inaccuracies. When an offset extension wrench is used with a torque wrench, the effective length of the torque wrench is changed. The torque wrench is so calibrated that when the extension is used, the indicated torque (the torque which appears on the dial or gage of the torque wrench) may be different from the actual torque that is applied to the nut or bolt. Therefore, the wrench must be preset to compensate for the increase when an offset extension wrench is used.

Occasionally, it is necessary to use a special extension or adapter wrench together with a standard torque wrench. In order to arrive at the resultant required torque limits, the following formula should be used.

$$S = \frac{T \times L}{(E + L)}$$

Where:

S = Reading of setting on torque wrench.

T = Recommended torque on part.

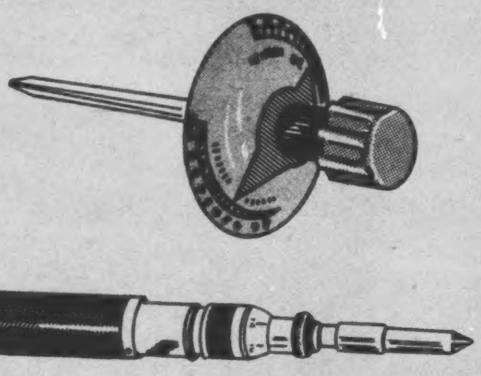
L = Length of torque wrench (distance between center of drive and center of hand grip).

E = Length of extension of adapter (distance between center of drive and center of broached opening measured in the same place as L).

EXAMPLE: Recommended torque is 100 inch-pounds. Using a 12-inch torque wrench and a 6-inch adapter, determine reading on torque wrench.

$$S = \frac{100 \times 12}{(6 + 12)} \quad \frac{1200}{18} = 66.6 \text{ inch-pounds}$$

When the extension is pointed back toward the handle of the torque wrench, subtract the effective length of the extension from the effective length of the torque wrench. If the extension is pointed at a right angle to the torque wrench, then the actual value does not change.



227.3

Figure 2-8.—Torque screwdrivers.

It is not advisable to use a handle extension on a deflecting beam type torque wrench at any time. A handle extension alone has no effect on the reading of other types. The use of a drive and extension on any other type of torque wrench makes the use of the formula mandatory. When applying the formula, force must be applied to the handle of the torque wrench at the point from which the measurements were taken. If this is not done, the torque obtained will be in error.

Torque Screwdrivers

A variety of torque tools is available, such as the small torque screwdrivers used on watches and instruments. Two types of torque screwdrivers are illustrated in figure 2-8. On one the pointer indicates the applied torque on a circular dial. The other is limited to a preset value in the handle causing it to turn freely when the torque value is reached.

Torque Controlled Power Tools

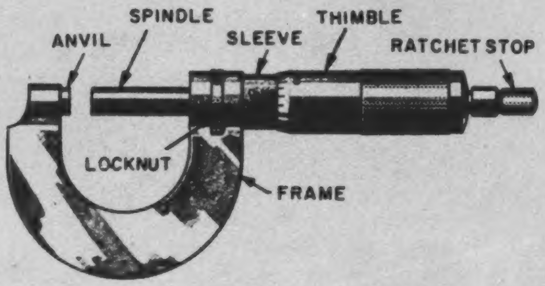
There are two types of torque controlled power tools. The torque controlled nutrunner and screwdriver are used to tighten screws and small nuts to torque values between 10 and 100 inch-pounds. The other torque power tool is a torque controlled impact wrench. It is used for tightening bolts and nuts to torque values between 20 and 100 foot-pounds. Both these tools operate on compressed air at 90 ±10 psi pressure. A flexible hose is used to connect the tool to the air supply.

A torque controlled nutrunner consists of an air motor fitted with a torque limiting device. A clutch in the torque limiter is released by the action of balls over-riding detents when sufficient resistance is encountered. When the tool is removed from the work, the clutch resets and is ready to tighten the next fastener. The torque at which the clutch releases is set by an adjustment that changes the pressure of the spring that holds the balls in the detents and is dependent on the rundown resistance of the fastener and the materials in the joint.

The torque controlled impact wrench consists of an air motor and a hammer mechanism. Torque is controlled by adjustable torsion bars. The three torsion bars provide low range–20 to 45 foot-pounds; medium range–40 to 65 foot-pounds; and high range–60 to 90 foot-pounds. The output torque of the tool is regulated by the amount of torque preset in the torsion bar. When the tool is applied to a fastener, the torsion bar functions as a rigid driving member until the fastener is tightened to a torque value equivalent to the preload torque in the bar. At this point the torsion bar acquires additional twist when the internal hammer in the tool strikes and unwinds between hammer blows. This rebounding action trips a mechanism that shuts off the air and stops the tool.

MICROMETER

It is important that a person who is working with machinery or in a machine shop thoroughly understand the mechanical principles, construction, use, and care of the micrometer. Figure 2-9 shows an outside micrometer caliper with the various parts clearly indicated. Micrometers are used to measure distances to the nearest one thousandth of an inch. The measurement is usually expressed or written as a decimal; so you must know the method of writing and reading decimals.



4.20.1A

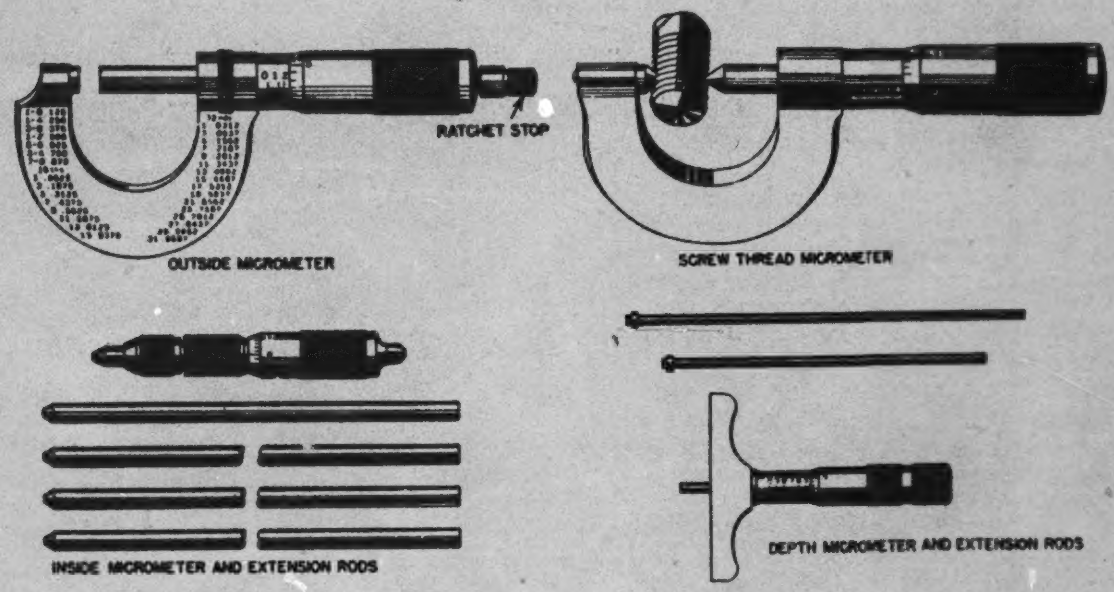
Figure 2-9.–Nomenclature of an outside micrometer caliper.

TYPES

There are three types of micrometers that are most commonly used throughout the Navy: the outside micrometer caliper (including the screw thread micrometer), the inside micrometer, and the depth micrometer. (See fig. 2-10.) The outside micrometer is used for measuring outside dimensions, such as the diameter of a piece of round stock. The screw thread micrometer is used to determine the pitch diameter of screws. The inside micrometer is used for measuring inside dimensions, as for example, the inside diameter of a tube or hole, the bore of a cylinder, or the width of a recess. The depth micrometer is used for measuring the depth of holes or recesses.

SELECTING THE PROPER MICROMETER

The types of micrometers commonly used are made so that the longest movement possible between the spindle and the anvil is 1 inch. This movement is called the "range." The frames of micrometers, however, are available in a wide variety of sizes, from 1 inch up to as large as 24 inches. The range of a 1-inch micrometer is from 0 to 1 inch; in other words, it can be used on work where the part to be measured is 1 inch or less. A 2-inch micrometer has a range from 1 inch to 2 inches, and will measure only work between 1 and 2 inches thick; a 6-inch micrometer has a range from 5 to 6 inches, and


RATCHET STOP
OUTSIDE MICROMETER
SCREW THREAD MICROMETER
INSIDE MICROMETER AND EXTENSION RODS
DEPTH MICROMETER AND EXTENSION RODS

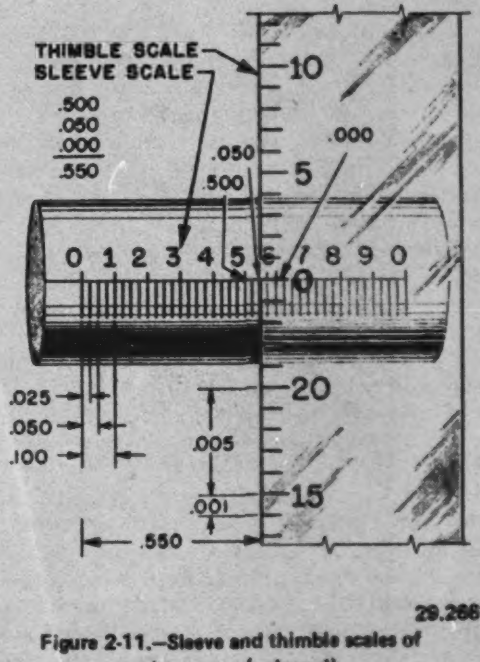
4.20.1B

Figure 2-10.—Common types of micrometers.

will measure only work between 5 and 6 inches thick. It is necessary, therefore, that the mechanic in selecting a micrometer first find the approximate size of the work to the nearest inch, and then select a micrometer that will fit it. For example, to find the exact diameter of a piece of round stock; use a rule and find the approximate diameter of the stock. If it is found to be approximately 3 1/4 inches, a micrometer with a 3- to 4-inch range would be required to measure the exact diameter. Similarly, with inside and depth micrometers, rods of suitable lengths must be fitted into the tool to get the approximate dimension within an inch, after which the exact measurement is ready by turning the thimble. The size of a micrometer indicates the size of the largest work it will measure.

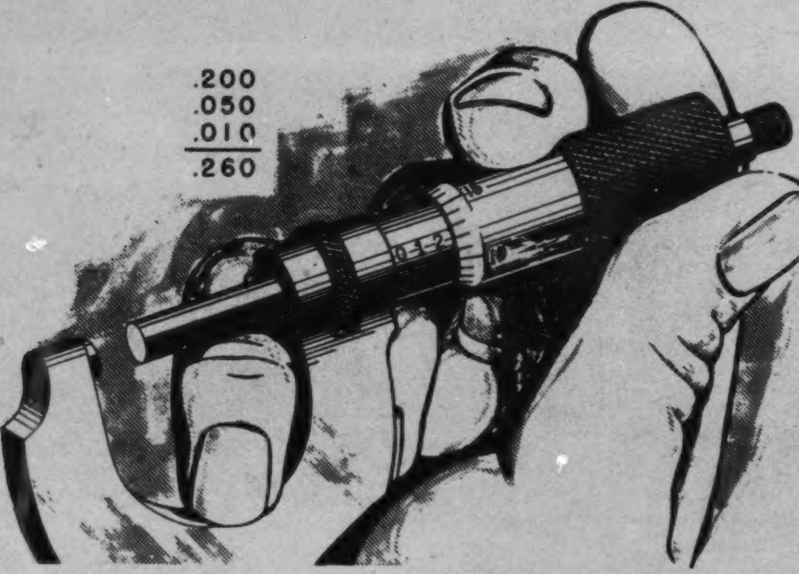
READING A MICROMETER CALIPER

The sleeve and thimble scales of the micrometer caliper have been enlarged in figure 2-11. To understand these scales, you need to


THIMBLE SCALE
SLEEVE SCALE
.500
.050
.000
.550
.050
.500
10
5
.000
0 1 2 3 4 5 6 7 8 9 0
0
20
.025
.050
.100
.005
.001
15
.550

29.266D

Figure 2-11.—Sleeve and thimble scales of a micrometer (enlarged).



4.20.2

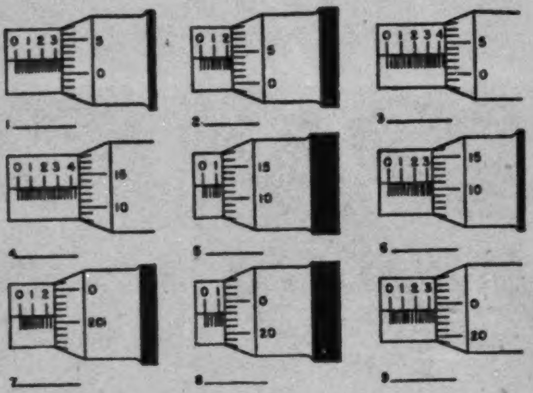
Figure 2-12.—Read a micrometer caliper.

know that the threaded section on the spindle, which revolves, has 40 threads per inch. Therefore, every time the thimble completes a revolution, the spindle advances or recedes 1/40" (0.025").

Notice that the horizontal line on the sleeve is divided into 40 equal parts per inch. Every fourth graduation is numbered 1, 2, 3, 4, etc., representing 0.100", 0.200", etc. When you turn the thimble so that its edge is over the first sleeve line past the "0" on the thimble scale, the spindle has opened 0.025". If you turn the spindle to the second mark, it has moved 0.025" plus 0.025" or 0.050". You use the scale on the thimble to complete your reading when the edge of the thimble stops between graduated lines. This scale is divided into 25 equal parts, each part representing 1/25 of a turn. And 1/25 of 0.025" is 0.001". As you can see, every fifth line on the thimble scale is marked 5, 10, 15, etc. The thimble scale, therefore, permits you to take very accurate readings to the thousandths of an inch, and, since you can estimate between the divisions on the thimble scale, fairly accurate readings to the ten thousandth of an inch are possible.

The closeup in figure 2-12 will help you understand how to take a complete micrometer reading. Count the units on the thimble scale and add them to the reading on the sleeve scale. The reading in the figure shows a sleeve reading of 0.250" (the thimble having stopped slightly more than halfway between 2 and 3 on the sleeve) with the 10th line on the thimble scale coinciding with the horizontal sleeve line. Number 10 on this scale means that the spindle has moved away from the anvil an additional 10 x 0.001" or 0.010". Add this amount to the 0.250" sleeve reading, and the total distance is 0.260".

Read each of the micrometer settings in figure 2-13 so that you can be sure of yourself when you begin to use this tool on the job. The correct readings are given following the figure so that you can check yourself.

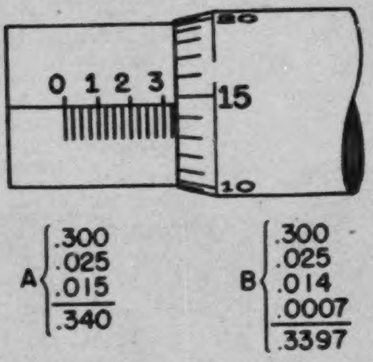


Answers for checking—

1. = 0.327
2. = 0.229
3. = 0.428
4. = 0.438
5. = 0.137
6. = 0.336
7. = 0.246
8. = 0.148
9. = 0.349

4.20

Figure 2-13.—Micrometer-reading exercises.



29.266F

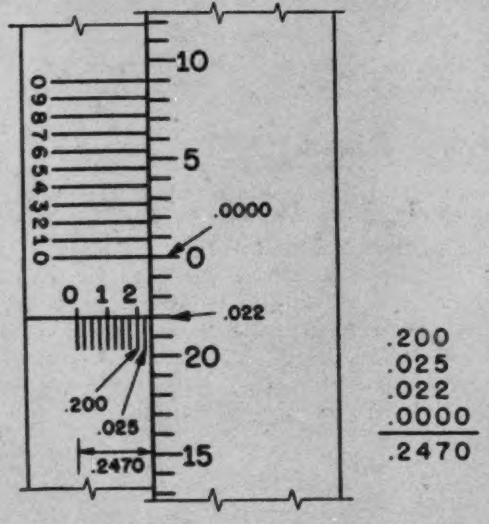
Figure 2-14.—Interpolating a micrometer reading.

Figure 2-14 shows a reading in which the horizontal line falls between two graduations on the thimble scale and is closer to the 15 graduation than it is to the 14. To read this to THREE decimal places, refer to figure 2-14 and calculation A. To read it to FOUR decimal places, estimate the number of tenths of the distance between thimble-scale graduations the horizontal line has fallen. Each tenth of this distance equals one ten-thousandth (0.0001) of an inch. Add the ten-thousandths to the reading as shown in calculation B of figure 2-14.

READING A VERNIER MICROMETER CALIPER

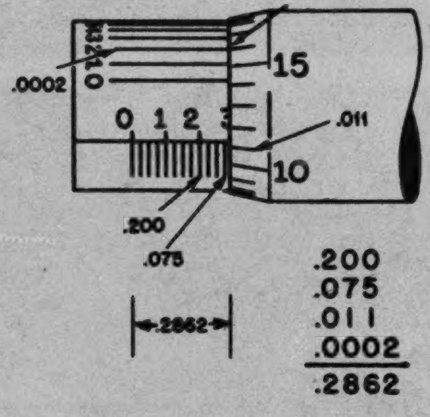
Many times you will be required to work to exceptionally precise dimensions. Under these conditions it is better to use a micrometer that is accurate to ten-thousandths of an inch. This degree of accuracy is obtained by the addition of a vernier scale. This scale, shown in figure 2-15, furnishes the fine readings between the lines on the thimble rather than making you estimate. The 10 spaces on the vernier are equivalent to 9 spaces on the thimble. Therefore, each unit on the vernier scale is equal to 0.0009" and the difference between the sizes of the units on each scale is 0.0001".

When a line on the thimble scale does not coincide with the horizontal sleeve line, you can



29.266G

Figure 2-15.—Vernier scale on a micrometer.



29.266H

Figure 2-16.—Read a vernier micrometer caliper.

determine the additional space beyond the readable thimble mark by finding which vernier mark coincides with a line on the thimble scale. Add this number, as that many ten-thousandths of an inch, to the original reading. In figure 2-16 see how the second line on the vernier scale coincides with a line on the thimble scale.

This means that the 0.011 mark on the thimble scale has been advanced an additonal 0.0002" beyond the horizontal sleeve line. When you add this to the other readings, the reading will be 0.200 + 0.075 + 0.011 + 0.0002 or 0.2862 ", as shown.

MEASURING HOLE DIAMETERS WITH AN INSIDE MICROMETER CALIPER

To measure the diameter of small holes from 0.2" to 1" in diameter, an inside micrometer caliper of the jaw type as shown in figure 2-17A may be used. Note that the figures on both the thimble and the barrel are reversed, increasing in the opposite direction from those on an outside micrometer caliper. This is because this micrometer reads inside measurements. Thus as you turn the thimble clockwise on this micrometer, the measuring surfaces move farther apart and the reading increases. (On an outside micrometer caliper, as you turn the thimble clockwise, the measuring surfaces move closer together and the reading decreases.)

For holes from 2" up to several feet in diameter, select the inside micrometer having extension rods whose range includes the required dimension. The extension rod marked "6-7," for example, when inserted into the head of the micrometer, will measure inside diameters from 6" to 7". The shoulder on the rod must seat properly to ensure a correct reading. Figure 2-17B shows that, for large measurements, both hands are used to set the micrometer for checking a diameter. Hold one end in place with one hand as you "feel" for the maximum possible setting by moving the other end from left to right, and in and out of the hole with the other hand. When no left-to-right movement is possible, and a slight drag is noticed on the in-and-out swing, take the reading.

MEASURING ROUND STOCK

When measuring the diameter of a small piece of round stock, hold the stock to be measured in one hand. Hold the micrometer in the other hand so that the thimble rests between the thumb and the forefinger. (See fig. 2-18.) The third finger is then in a position to hold the frame against the palm of the hand. The frame is supported in this manner and makes it easy to guide the work over the anvil. The thumb and

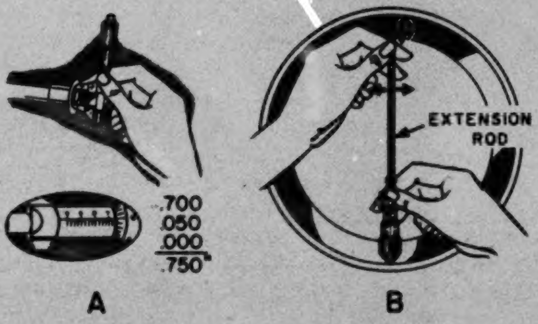


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Figure 2-17.—Measuring an inside diameter with an inside caliper.

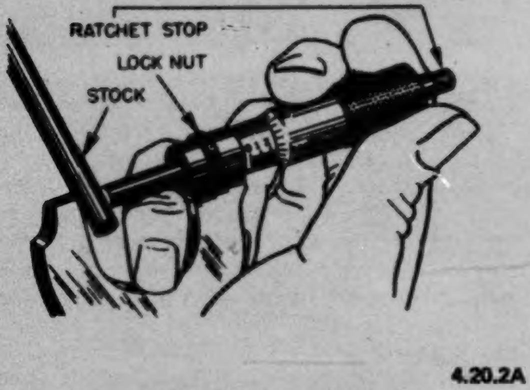


Figure 2-18.—Measuring round stock with a micrometer caliper.

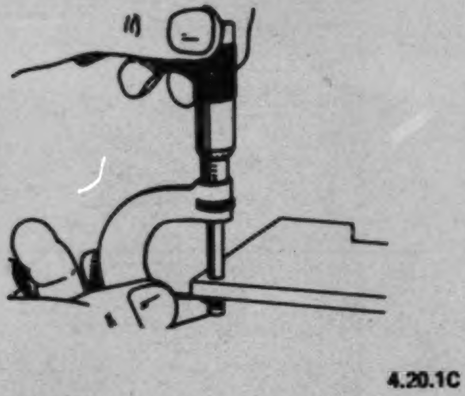


Figure 2-19.—Measuring flat stock with a micrometer caliper.

forefinger are in position to turn the thimble either directly or through the ratchet and bring the spindle over against the surface being measured.

Turn the spindle down to contact by "feel," or else use the ratchet stop. Your feel should produce the same contact pressure and therefore the same reading as that produced when the ratchet stop is used. Develop your "feel" by measuring a certain dimension both with and without the aid of the ratchet stop. When you have the correct feel, you will get the same readings by both methods.

In measuring round stock the feel must be very light because there is only a line contact between the spindle and the stock and the anvil and the stock. Therefore the contact area is exceptionally small, causing a proportionally high contact pressure per unit of area. This tends to give a reading smaller than the true reading unless the light feel is used. Moreover, in measuring a ball from a ball bearing, the contact is at only two points, so the contact area is again very small, which results in a tremendous pressure per unit of area. This condition requires only the lightest possible contact pressure to give a true reading.

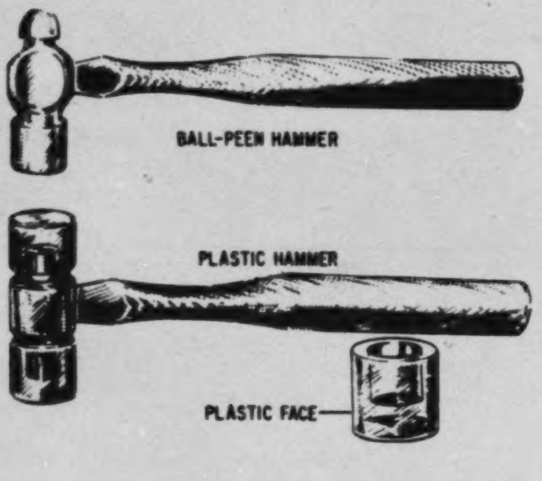
Hold the micrometer lightly and for only as long as is necessary to make the measurement. Wrapping the hand around it or holding it for too long a time will cause expansion of the metal and will introduce errors in measurement. Read the setting on the thimble scale (if the object is small) without removing the micrometer caliper from the object.

MEASURING A FLAT SURFACE

When measuring a flat surface with a micrometer caliper, the entire area of both the anvil and the spindle is in contact with the surface being measured. This causes a proportionally low contact pressure per unit of area. Therefore the "feel" should be slightly heavier than when measuring round stock.

On large flat work, it is necessary to have the work stationary and positioned to permit access for the micrometer. The proper method of holding a micrometer when checking a part too large to be held in one hand is shown in figure 2-19. The frame is held by one hand to position it and to locate it square to the measured surface. The other hand operates the thimble either directly or through the ratchet. A large flat surface should be measured in several places to determine the amount of variation. It is good practice to lock the spindle in place with the locknut before removing the micrometer from the part being measured. After removal of the micrometer the measurement indicated on the thimble scale can then be read.

To retain a particular setting, in cases where several pieces are to be gaged, lock the spindle in place with the locknut. When a piece is "gaged"



213.23

Figure 2-20.–Hammers.

with a micrometer whose spindle is locked to a particular setting, the piece can quickly be identified as oversize, correct size, or undersize.

CARE OF MICROMETERS

Keep micrometers clean and lightly oiled. Make sure they are placed in a case or box when they are not in use. Anvil faces must be protected from damage and must not be cleaned with emery cloth or other abrasive.

STRIKING TOOLS

HAMMERS

Generally speaking, this group is composed of various types of hammers, all of which are used to apply a striking force where the force of the hand alone is insufficient. Each of these hammers is composed of a head and a handle, even though these parts differ greatly from hammer to hammer. So that the ASM may have a better idea of their differences and uses, let's consider the types of hammers used most frequently. (See fig. 2-20.)

The ball-peen hammer is sometimes referred to as a machinist's hammer. It is a hard-faced hammer made of forged tool steel.

The flat end of the head is called the face. This end is used for most hammering jobs. The other end of the hammer is called the peen. The peen end is smaller in diameter than the face and is therefore useful for striking areas that are too small for the face to enter.

Ball-peen hammers are made in different weights, usually 4, 6, 8, and 12 ounces and 1, 1 1/2, and 2 pounds, For most work, a 1 1/2-pound and a 12-ounce hammer will suffice.

A mallet is a soft faced hammer. Mallets are constructed with heads made of brass, lead, tightly rolled strips of rawhide, and plastic or plastic with a lead core for added weight.

Plastic mallets similar to the one shown in figure 2-20 are the type normally found in the ASM's toolbox. The weight of the plastic head may range from a few ounces to a few pounds. The plastic mallet may be used for straightening thin sheet ducting or when installing clamps.

Hammers are dangerous tools when used carelessly and without consideration. Practice will help the ASM to learn to use a hammer properly. Some important things to remember when using a hammer or mallet are as follows:

Hold the handle near the end with the fingers underneath and the thumb along the side or on top of the handle. The thumb should rest on the handle and never overlap the fingers. Oils on the face of the hammer will cause it to glance off the work; therefore, wipe the oil off with a rag then rub the face with coarse sandpaper or emery cloth. Never use a hammer which has a loose head or cracked handle. It is dangerous to personnel and to property. Most hammer accidents are caused by a loose head or a slippery handle. so remember this when using any kind of striking tool. Tighten the loose hammerhead by driving a wedge in the end of the handle. This spreads the handle tightly inside the head. Do not strike a hardened steel surface with a steel hammer. Small pieces of steel may break and injure someone or damage the work. Use a soft hammer in striking hardened steel or highly polished stock. If a soft hammer is not available, use a piece of copper, brass, lead, or wood to protect the hardened steel. However, it is permissible to strike a punch or chisel directly with the ball-peen hammer because the steel in the heads of punches and chisels is slightly softer than that of the hammer head.

HOLDING TOOLS

VISE GRIP PLIERS

The ASM uses this tool a number of ways. These pliers can be adjusted to various jaw openings by turning the knurled adjusting screw at the end of the handle. Vise grips can be clamped and locked in position by pulling the lever toward the handle. The vise grip pliers are shown in figure 2-21. They may be used as a clamp, speed wrench, portable vise, and for many other uses where a locking, plier-type jaw may be employed.

CAUTION: Vise grip pliers should be used with care since the teeth in the jaws tend to damage the object on which they are clamped. They should not be used on nuts, bolts, tube fittings, or other objects which must be reused.

CHANNEL-LOCK PLIERS

Channel-lock pliers (fig. 2-22) can be easily identified by the extra-long handles, which make them a very powerful gripping tool. The inner surfaces of the jaws consist of a series of coarse teeth formed by deep grooves, a surface adapted to grasping cylindrical objects. Channel locks have grooves on one jaw and lands on the other. The adjustment is effected by changing the position of the grooves and lands. The channel locks are less likely to slip from the adjustment setting when gripping an object. The channel-lock pliers will only be used where it is impossible to use a more adapted wrench or holding device. Many nuts and bolts and surrounding parts have been damaged by improper use of channel-lock pliers.

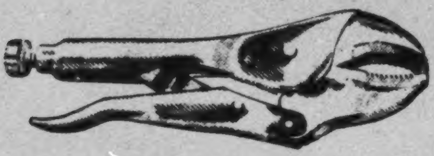

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Figure 2-21.—Vise grip pliers.

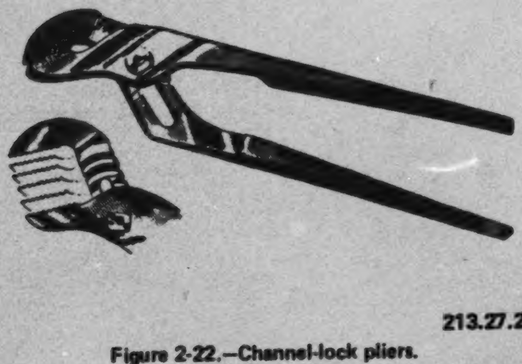
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Figure 2-22.—Channel-lock pliers.

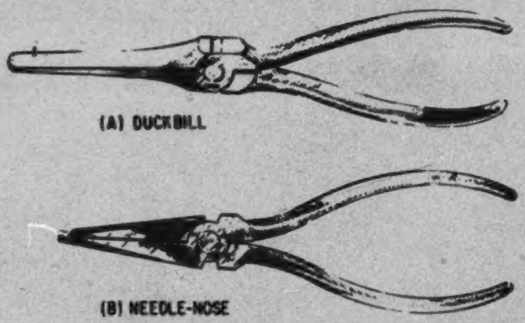

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Figure 2-23.—Pliers. (A) Duckbills; and (B) needle-nose.

DUCKBILL PLIERS

Duckbill pliers (A, fig. 2-23) have long wide jaws and slender handles. Duckbills are used in confined areas where the fingers cannot be used. The jaw faces of the pliers are scored to aid in holding an item securely.

NEEDLE-NOSE PLIERS

Needle-nose pliers (B, fig. 2-23) are used in the same manner as duckbill pliers. However, there is a difference in the design of the jaws. Needle-nose jaws are tapered to a point which makes them adapted to installing and removing small cotter pins. They have serrations at the nose end and a side cutter near the throat.

Needle-nose pliers may be used to hold small items steady, to cut and bend wire, or to do numerous other jobs which are too intricate or too difficult to be done by hand alone.

NOTE: Duckbill and needle-nose pliers are especially delicate. Care should be exercised when using these pliers to prevent springing, breaking, or chipping the jaws. Once these pliers are damaged, they are practically useless.

MISCELLANEOUS TOOLS

MECHANICAL FINGERS

Small articles which have fallen into places where they cannot be reached by hand may be retrieved with the mechanical fingers. This tool is also used when starting nuts or bolts in difficult areas. The mechanical fingers, shown in figure 2-24, have a tube containing flat springs which extend from the end of the tube to form clawlike fingers, much like the screw holder. The springs are attached to a rod that extends from the outer end of the tube. A plate is attached to the end of the tube, and a similar plate to be pressed by the thumb is attached to the end of the rod. A coil spring placed around the rod between the two plates holds them apart and retracts the fingers into the tube. With the bottom plate grasped between the fingers and enough thumb pressure applied to the top plate to compress the spring, the tool fingers extend from the tube in a grasping position. When the thumb pressure is released, the tool fingers retract into the tube as far as the object they hold will allow. Thus, enough pressure is applied on the object to hold it securely. Some mechanical fingers have a flexible end on the tube to permit their use in close quarters or around obstructions.

NOTE: Mechanical fingers should not be used as a substitute for wrenches or pliers. The fingers are made of thin sheet metal and can be easily damaged by overloading.

STEEL SCALE

The steel scale shown in figure 2-25 is a measuring device that will usually be found in the ASM's toolbox. It is graduated in divisions of 1/8 and 1/16 inch on one side and 1/32 and 1/64 inch on the other side. The steel scale most commonly used is 12 inches long.

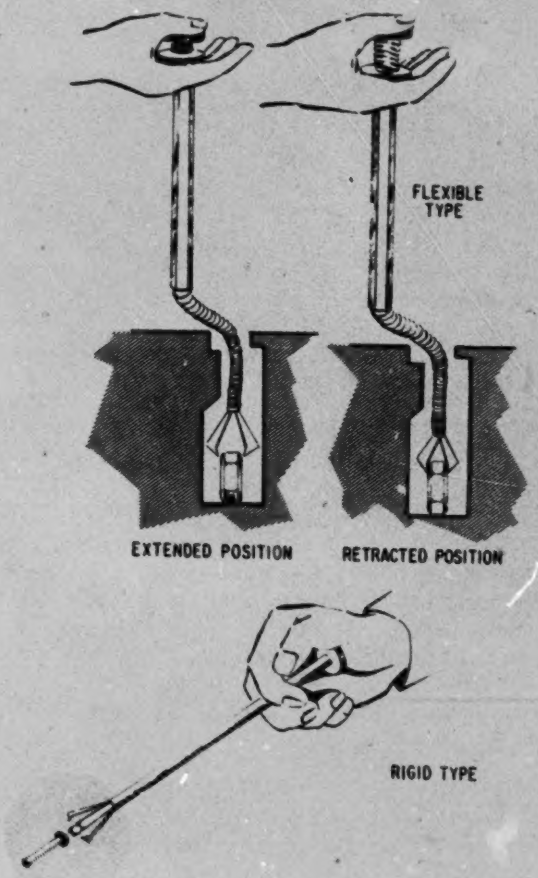

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Figure 2-24.—Mechanical fingers.

Measurements are taken with a steel scale by holding it on its edge on the surface of the subject being measured. This will prevent making errors which might be caused by the thickness of the scale. Such thickness causes the graduations to be a slight distance away from the surface of the object. Measurements are read at the graduation which coincides with the distance to be measured.

FLASHLIGHT

Each toolbox should have a standard Navy vaporproof two-cell flashlight. The flashlight is used constantly during all phases of maintenance. Installed in both ends of the flashlight are rubber seals which keep out all vapors. The flashlight should be inspected periodically for the installation of these seals, the spare bulb, and colored filters which are contained in the end cap.

NOTE: Do not throw away the filters; they will be necessary during night work on or near the aircraft line.

INSPECTION MIRROR

There are several types of inspection mirrors available for use in aviation support equipment maintenance. The mirror is issued in a variety of sizes and may be round or rectangular. The mirror is connected to the end of a rod and may be fixed or adjustable. (See fig. 2-26.)

The inspection mirror aids in making detailed inspection where the human eye cannot directly see the inspection area. By angling the mirror, and with the aid of a flashlight, it is possible to inspect most required areas.

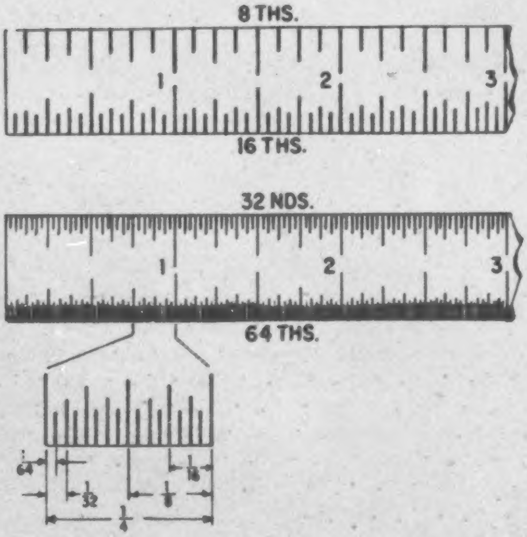

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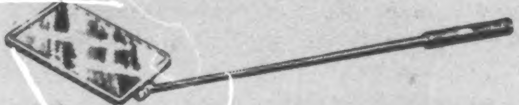
Figure 2-25.—Scale rule.



213.28.2

Figure 2-26.—Typical inspection mirror.

CARE OF TOOLS

This is the time in your Navy career when you must begin to develop good habits of tool care. The use of tools is necessary in order for you to put the knowledge you acquire on maintenance of aviation support equipment into practice in repairing equipment. It cannot be too strongly emphasized that the care you give your tools is a contributing factor in your efficiency in the maintenance of aviation support equipment.

Each tool is designed for a certain use; turning a nut, measuring something, holding a part, straightening a piece of metal, or other required operation. Use the tool for the purpose for which it was designed. For example, do not pry with a screw driver, use only a hammer to hammer, etc. When a tool becomes broken or sprung or a hammer head loose on the handle, replace the broken tool and tighten the hammer head on the handle before using again.

Keep tools in a certain place in the toolbox. This will enable you to locate a tool without digging all through the box before finding what you want. Junk, such as used bolts and nuts, short pieces of wire, used cotter pins, etc., should not be kept in the toolbox. When beginning a repair job lay all the tools you think you will need out of the toolbox in a convenient place such as a bench, tool stand, or on a cloth on the ground if no other convenient place is available. As the work progresses mentally keep ahead of your hands by deciding what tool you will need next and whether the tool is at hand or in the box. This will permit you to use the proper tool for the work and will permit the work to move forward as rapidly as possible.

After the job is finished, inspect all the tools you have used. Remove rough edges that have resulted from your work and clean all tools before replacing in the box. Lay aside tools that need to be replaced so that you may trade them for usable tools at the toolcrib. If you have used special tools, gather them together for return to the checkout point. As you replace the tools in the box mentally inventory them to make sure you have gathered all the tools you used and have not left any lying around the job. Look over the equipment you were working on to make sure no tools are left in or on the equipment. Proper care of tools can help you feel the satisfaction of accomplishing a job rapidly and correctly.

SPECIAL TOOLS

In order to become a skilled mechanic you must not only know the principle of construction of aviation support equipment, but you must also be able to identify the tools and equipment required to repair the vehicles and keep them in good operating condition. Handtools, measuring devices, and fastening methods play an important part in every repair job.

It is important from the standpoint of skill and efficiency that you use a tool properly, and use it for the job for which it is designed. A screwdriver, for example, is designed to loosen or tighten screws. It can withstand a considerable twisting force in relation to its length and thickness, but a screwdriver used as a chisel or pry bar can be easily bent or broken.

A few special tools are described in this training manual in the sections which cover specific items of equipment that require special tools for repair and maintenance. For example, the special tools required to repair and service a given model of automatic transmission are described in chapter 10.

A great variety of power-driven tools and equipment is used by the ASM. The common power tools, such as drill motors and bench grinders, are described in Part I Section 2 of *Tools and Their Uses*, NAVPERS 10085 (Series). Only the more specialized tools and equipment are covered in this section.

ENGINE TESTING EQUIPMENT

Satisfactory performance and dependability are what every equipment operator desires most from his vehicle. It is the mechanics' obligation, therefore, to perform all the service necessary to insure or restore this performance and dependability. Each time you are confronted with a vehicle against which an operator has registered a performance complaint, you must know the cause of the difficulty before determining what corrective measures must be taken. In most shops, the Navy provides accurate and dependable test equipment. The proper use of this equipment provides the quickest and surest means of finding out what is wrong and where the fault lies with the vehicle operation.

Tachometer

A tachometer is a speed indicating device used to measure the rpms (revolutions per minute) of a rotating shaft. Since many engine tests are made at specified engine speeds, you should learn how to use a tachometer.

Tachometers may be either manually or electrically operated. When using the manual tachometer on a shaft, make sure the shaft turns the same speed as the crankshaft or you will not get an accurate reading of engine rpms. In many instances it is easy to take tachometer readings off the camshaft or fuel pump shaft. On 4-cycle engines these shafts run one-half engine speed. Consequently any tachometer reading taken from these shafts must be doubled to get the true engine rpm.

A manual tachometer (fig. 2-27) is used by holding its tip against the end of a rotating shaft. Make sure the end of the shaft is clean and that there is no slippage between the tip of the tachometer and the shaft. Read the speed directly on the tachometer dial, which is

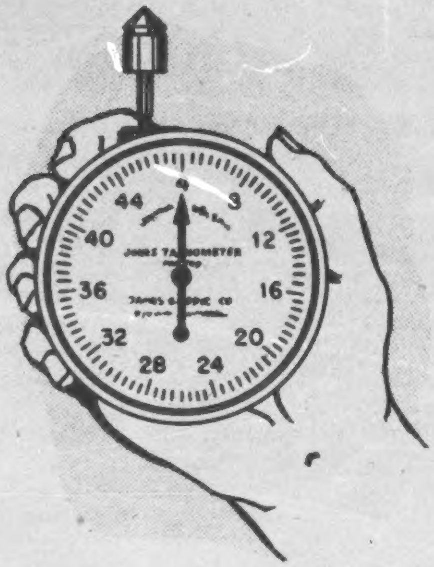


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Figure 2-27.—Manually operated tachometer.

calibrated in revolutions per minute. No timing is necessary as variations in speed will be reflected by movement of the pointer on the dial during the test.

The electric tachometer is connected to the ignition primary circuit to measure the number of times per minute the primary circuit is interrupted. It then translates this information into engine rpm.

The electric tachometer may have a selector switch on it that can be turned to correspond with the number of lobes on the distributor cam. The number of lobes will be the same as the number of cylinders in the engine. For the proper method of hooking up and using the electric tachometer, check the manufacturer's instructions for the tachometer you are using.

Compression Tester

The cylinder compression tester (fig. 2-28) is used to measure cylinder pressure in psi (pounds per square inch) as the piston moves to TDC (top dead center) on the compression stroke.

To use the compression tester, remove all the spark plugs from the engine. Hold or screw the tester fitting tightly in one of the spark plug holes. Crank the engine with the starting motor until it makes at least four complete revolutions. Notice the maximum compression as indicated by the needle on the compression tester dial. Repeat this procedure until the compression has been checked on all cylinders of the engine.

The compression of the engine must meet the manufacturer's specifications in order for the engine to develop rated power. This means that there must be no leakage in the cylinder. The intake and exhaust valves, the gaskets, and piston rings must all function properly and allow no leakage for full power output. An engine with low compression in one or more cylinders will have uneven power strokes which result in rough operation, and in a proportionate reduction in performance.

Cylinder Leakage Tester

The cylinder leakage tester will, when properly used, give a good indication of the condition of an engine cylinder. This tester (fig. 2-29) applies air to the cylinder at controlled volume and pressure, and measures the percentage of air leakage. Even the smallest leak can be easily detected.

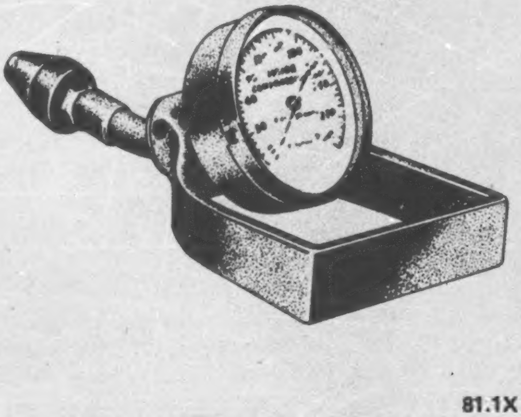

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Figure 2-28.—Cylinder compression tester.

It is normal for a small amount of air to escape past the rings into the crankcase. However, any leak through an intake valve, an exhaust valve, head gasket, head, block, or excessive leakage past the rings, indicates trouble which must be corrected before satisfactory engine performance can be expected.

To use the cylinder leakage tester, hook it to the cylinder as recommended by the equipment manufacturer. Listen for escaping air through the carburetor, the exhaust or tail pipe, and the crankcase filler pipe. Check for air bubbles in the radiator.

Vacuum Gage

The vacuum gage (fig. 2-30) provides a means of testing intake manifold vacuum, cranking vacuum, fuel pump vacuum, and booster pump vacuum. Properly used, the vacuum gage will indicate if other tests are necessary. The vacuum gage does not replace other test equipment, but rather supplements it, and makes a diagnosis of engine trouble more conclusive.

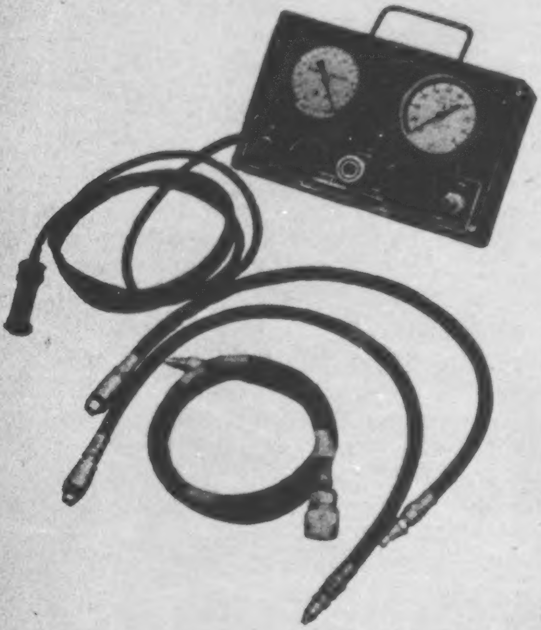

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Figure 2-29.–Cylinder leakage tester.

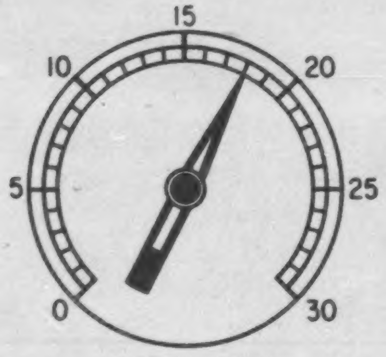
227.7

Figure 2-30.–Manifold vacuum gage connection.

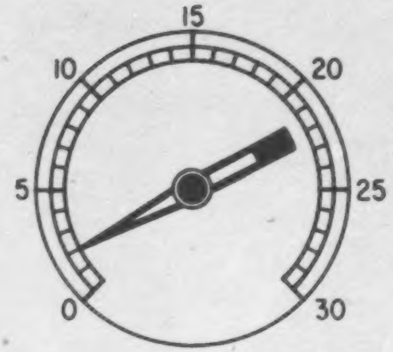
The manifold vacuum test provides an overall check on the engine condition based on comparison of reading obtained with known standards for the engine being tested. Any loss of power or efficiency in the engine will affect the manifold vacuum reading.

Vacuum gage readings are usually taken with the engine running and must be accurate to be of any value. Therefore, when connecting the gage to the intake manifold, be sure the connection is leakproof. Also, before the connection is made, make sure the openings to the gage and intake manifold are free from dirt or other restrictions.

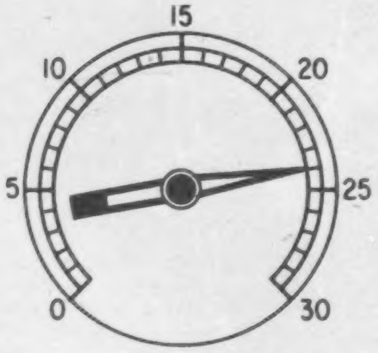
Experience is the best guide in determining the normal vacuum for any given engine. Normal manifold vacuum ranges from 15 to 22 inches on various engines when the test is being made at sea level pressures. The average reading will drop approximately 1 inch for each 1,000 feet above sea level. The reading obtained is the difference between normal atmospheric pressure and the reduced pressure within the mainfold of the running engine. This difference in pressure forces the air-fuel (gasoline) or air (diesel)



NORMAL IDLE



THROTTLE OPENED SUDDENLY



MAX READING AFTER THROTTLE IS OPENED SUDDENLY

227.8

Figure 2-31.—Approximate vacuum gage readings on a normal operating engine.

mixture into the cylinders. For this reason, any abnormal vacuum gage reading will indicate improper operation. The action of the pointer on the gage is the most important factor in interpreting the reading to determine the internal trouble of the engine.

When you open and close the throttle suddenly, the vacuum reading should first drop to about 2 inches with the throttle open and then come back to a high of about 24 inches before settling back to a steady 18 inches as the engine idles. (See fig. 2-31.) This is normal for an engine in good operating condition.

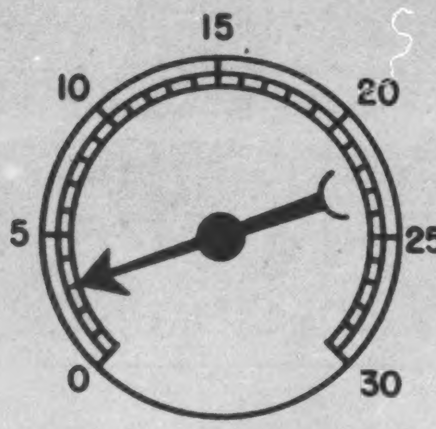
If the gage reading drops to around 15 inches at a running speed of about 40 mph (miles per hour) and remains there, it indicates compression leaks between the cylinder walls and the piston rings, or power loss caused by incorrect ignition timing. A vacuum gage needle indicating a steady 10, for example, usually means that the valve timing of the engine is incorrect. Below normal readings that change slowly between two positions, such as 14 to 16 inches, could point to a number of troubles, which might be any of the following: (1) improper carburetor idling adjustments, (2) maladjusted or burned breaker points, (3) spark plugs with the electrodes set too close.

A sticking valve could cause the gage needle to bounce from a normal steady reading to a lower reading and back to normal. A broken or weak valve spring would cause a wide variation of the needle as the engine is accelerated. A loose intake manifold, or a leaking gasket between the carburetor and manifold, would show a steady low reading on the vacuum gage. (See fig. 2-32.)

You must remember that manifold vacuum tests only help you locate trouble. They are not always conclusive, but through experience and skill and correct interpretation of the readings, in conjunction with the compression test results, you can usually diagnose engine behavior correctly.

Exhaust Gas Analyzer

An exhaust gas analyzer (combustion efficiency tester) checks the exhaust gas to



2.27

Figure 2-32.—Low vacuum gage reading indicating a leak in the intake manifold.

determine what percentage of the gasoline has not been burned. Combustion efficiency is a very reliable indication of carburetor system operation on a mechanically sound, properly tuned engine with a good ignition system. If your shop has one of these instruments, learn to use it properly.

Combustion efficiency is tested by utilizing exhaust gas samples picked up at the tailpipe to determine the fuel to air ratio. This information is indicated on an electric meter. The pointer on the meter is affected by the amount of hydrogen and carbon in the exhaust gas that runs through the analyzer. Check the manufacturer's manual for the equipment you are using to interpret the reading on the meter of the analyzer. When the readings are correctly interpreted, you can tell whether the carburetor needs adjustment.

Before testing, determine that both compression and ignition of the engine to be tested are in good condition, and that the exhaust system does not leak. Smoke from an engine that is burning oil does not materially affect the accuracy of an exhaust analyzer during the test. Repeated use of a combustion efficiency tester on oil burning engines will eventually decrease its sensitivity because of oil fouling.

Dynamometers

A dynamometer is an instrument for measuring the horsepower an engine develops. This instrument consists of a resistance creating device, such as an electric armature revolving in a magnetized field. A paddle wheel revolving in a fluid may also be used to absorb the energy.

An engine dynamometer may be used to test an engine that has been removed from the vehicle it drives. If the engine does not develop the manufacturer's recommended horsepower and torque at specific rpms, you know there is need for further adjustments and/or repairs on the engine.

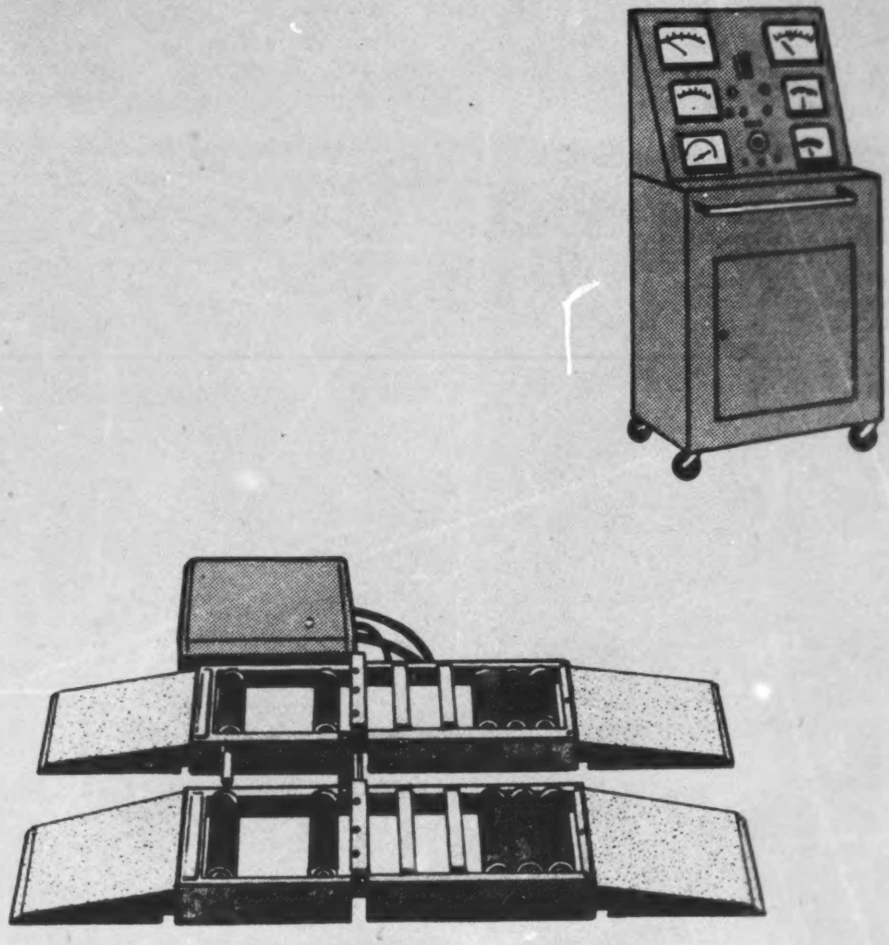
The chassis dynamometer (fig. 2-33) is commonly used for automotive service, since it can give a very quick report on engine conditions by measuring output at various speeds and loads. This type of machine is very useful in shop testing and adjusting automatic transmissions.

On the chassis dynamometer, the driving wheels of the vehicle are placed on rollers. The engine drives the wheels and the wheels drive the rollers. By loading the rollers varying amounts and by running the engine at different rpms, nearly all normal driving conditions can be simulated. The tests and checks can be made without the interference of body noises, such as you would have when checking the vehicle on the road.

Be sure you read and understand the operator's manual on the dynamometer before attempting to use it. The machine is rather complex and can be damaged by improper handling; like all equipment, it is worthless if not in working order.

Ignition Stroboscope (Timing Light)

Later in this manual you will learn how the air-fuel or air mixture is ignited. For the present, it is enough to know that ignition must take place at the proper instant. An instrument called



226.25

Figure 2-33.—Chassis dynamometer.

an ignition timing light (fig. 2-34) is used to check engine timing on a gasoline engine. A timing light is basically a neon light powered by the battery of the vehicle being tested. The vehicle being timed will have a timing mark on the flywheel or the crankshaft pulley. A timing pointer is fastened to some stationary part of the engine. If the ignition is properly timed, the timing mark will line up with the fixed pointer each time the timer flashes. The flash occurs the instant the spark plug from cylinder number 1 fires. Later in this manual you will learn more about engine timing.

VALVE REPAIR EQUIPMENT

Valve repair equipment is composed of an assortment of machine tools and components that are designed for reconditioning valves of internal combustion engines, in accordance with engine manufacturer's specifications. Reconditioning valves is a precision job. Therefore, if you are in doubt about how to use a valve repair tool, consult the equipment manufacturer's instructions or have an experienced mechanic show you. In any case, find out how to properly use valve repair

242

Figure 2-34.–Using a timing light.

equipment before trying to do a complete valve job by yourself.

Valve Refacer

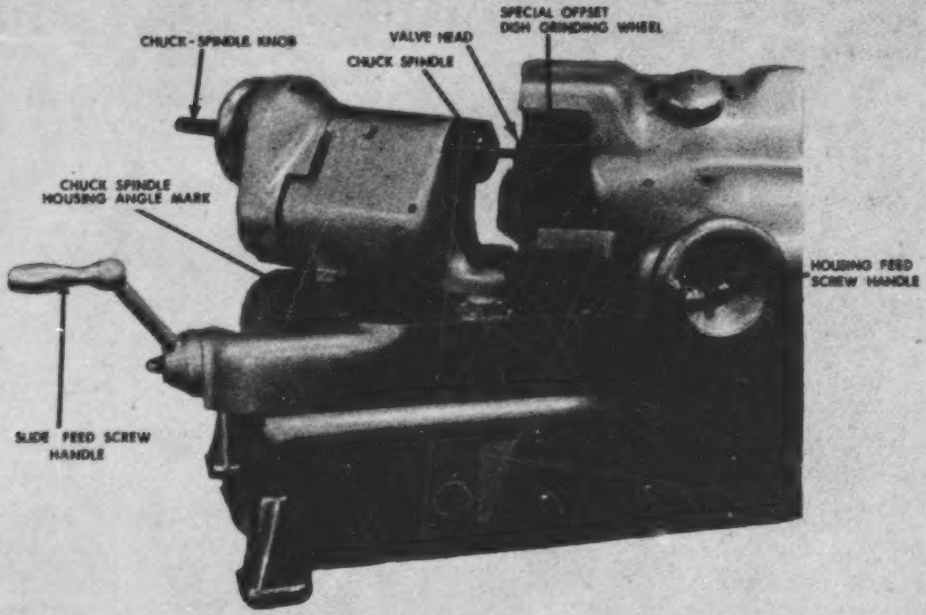
The valve refacing machine (fig. 2-35) is used to remove small pits or burns from the valve face. This is accomplished by clamping the valve stem in the chuck of the refacing machine and bringing the rotating grinding wheel into contact with the seating face of the valve.

Valve refacing machines have attachments for dressing their grinding wheels, truing tappets, squaring valve stems, and for grinding valve rocker arm faces.

Valve Seat Grinder

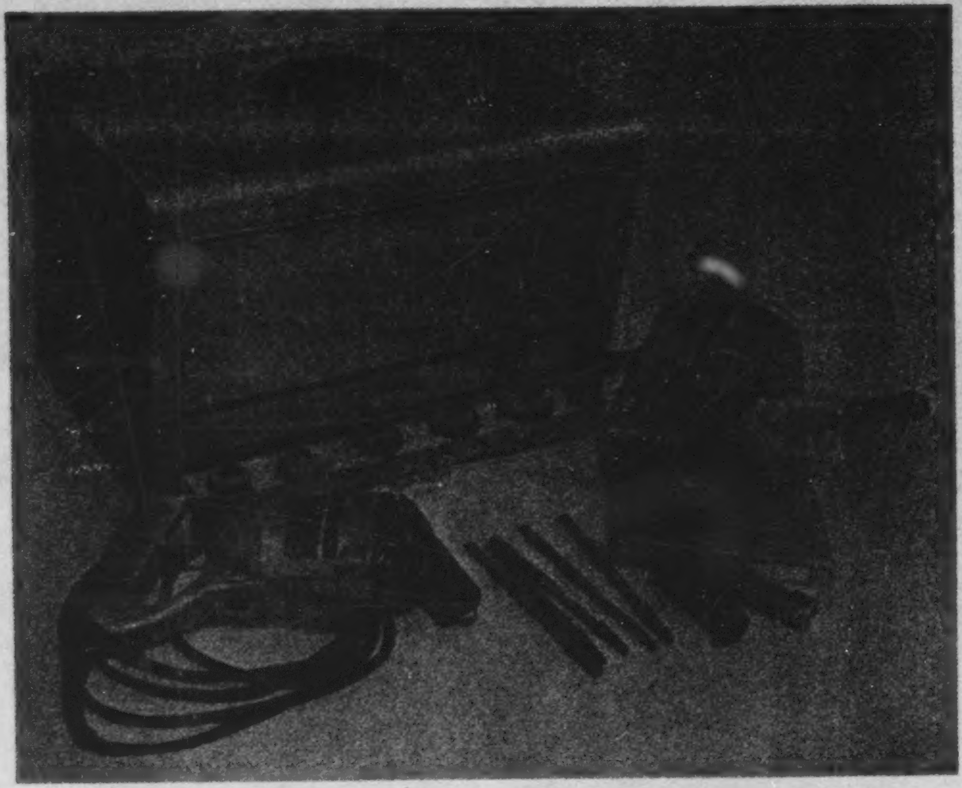
Valve seat grinding equipment (fig. 2-36) consists of a driver, pilots, grinding stones, a stone dressing stand, and stone sleeves.

The driver provides the power for valve seat grinding. There are different kinds and designs you may encounter, but one popular model


SPECIAL OFFSET
DISH GRINDING WHEEL
CHUCK-SPINDLE KNOB
VALVE HEAD
CHUCK SPINDLE
CHUCK SPINDLE
HOUSING ANGLE MARK
HOUSING FEED
SCREW HANDLE
SLIDE FEED SCREW
HANDLE

226.38

Figure 2-35.–Valve refacing machine.

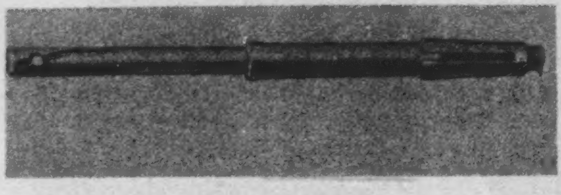


227.10

Figure 2-36.—Valve seat grinding equipment.

employs an angular head design to permit easier handling in confined spaces. Most drivers incorporate a positive vibrating action, which lifts the grinding stone from the seat once each revolution. This minimizes stone loading, speeds up grinding, and reduces stone wear.

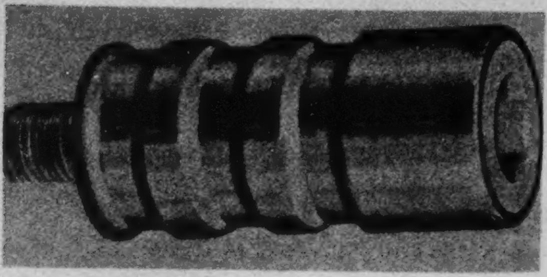
Most valve guide pilots are of the self-centering type. Their function is to provide a rigid axis for the grinding stone sleeves, so that the valve seats are refaced concentric with valve guides. The self-centering pilots have two machined tapers—one at the top of the shank to fit the top of the valve guide, and one at the bottom, to expand a split sleeve in the lower end of the guide. (See fig. 2-37.) To select the proper size pilot, refer to valve guide specifications of the engine manufacturer.



2.29X

Figure 2-37.—Self-centering valve guide pilot.

The valve seat grinding stone sleeves are attachments that fit over the pilot. They are threaded on one end for attaching the stone (fig. 2-38). The upper end has a socket which forms a universal joint connection with the end of the driver spindle.



2.30X

Figure 2-38.—Valve seat grinding stone sleeve.

Valve seat grinding stones are made in three grades: one grade is for the average cast iron seats found in most engines; another is for faster grinding of hard steel, stellite, and other hard alloy inserts; a third is for "finish grind" on all seats. A threaded steel bushing is cast in the center of each stone to thread on the stone sleeves.

After the stones are placed on the stone sleeve, they should be dressed on the stone dressing stand to establish a true angle to the pilot.

Valve Lapper

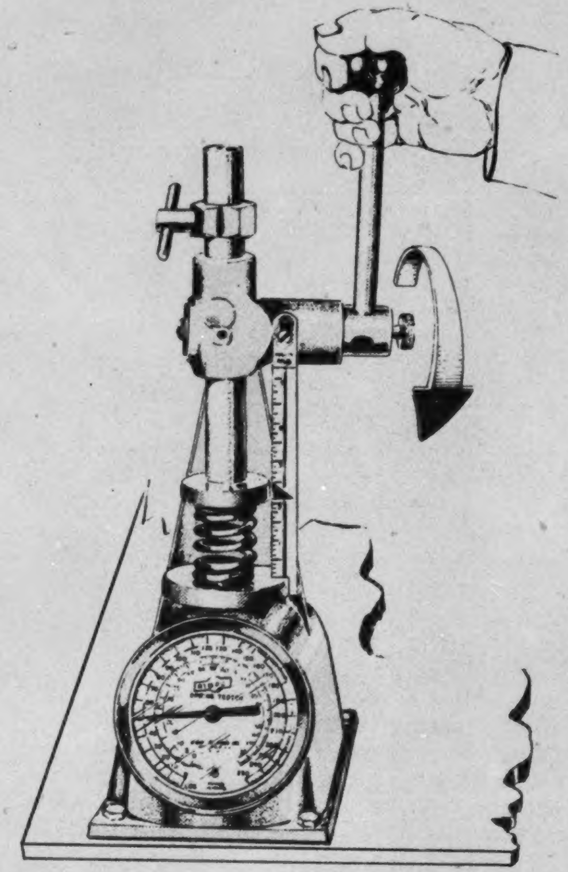
The final process involved in fitting a newly ground valve to its seat consists of rotating the valve in its closed position, thus rubbing the valve seating face against the valve seat. This is called lapping, and is done with a valve lapper. *Tools and Their Uses,* NAVPERS 10085 (Series), includes an illustrated discussion of a hand driver valve lapper.

Valve Spring Tester

A valve spring tester (fig. 2-34) is used to test valve springs for proper tension. A valve spring that is too weak will not seat the valve properly and thus cause it to burn. A spring that is too strong will cause undue wear on the valve operating mechanism. The engine manufacturer's manual will give the proper tension that is required of the valve springs. Any valve springs that do not have the proper tension or are warped or short, should be discarded.

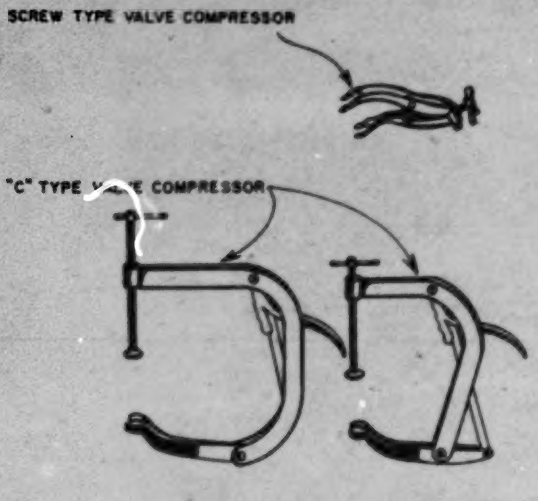
Valve Spring Compressor

Valve spring compressor is the name given to the tool that compresses the valve spring so the retaining locks can be removed from the valve stem. Two types of valve spring compressors (fig. 2-40) are generally used in the Navy. The "C" clamp compressor is used on overhead valve engines and has a screw adjusting post that adapts the tool to various valve stem lengths. The jaws on the bottom of the tool are adjustable to the valve spring diameters.



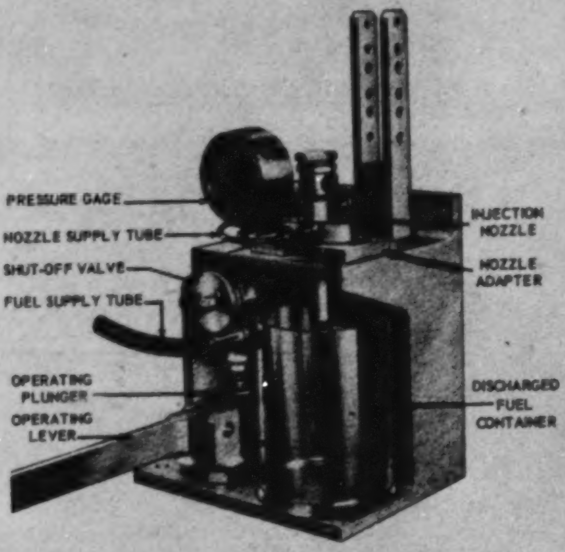
227.11

Figure 2-39.—Valve spring tester.



227.12

Figure 2-40.—Valve lifters for L-head and valve-in-head engines.



121.14X

Figure 2-41.—Universal test stand.

The screw-type valve spring compressor, shown in figure 2-40, is generally used on L-head engines having straight stemmed valves. Top jaws adjust to various spring diameters.

INJECTOR NOZZLE TESTER

An incorrect nozzle opening pressure or incorrect injector pop pressure will influence engine efficiency and performance. The exact effect will vary according to the type of combustion space served. When opening pressure is greater that the specified value, it tends to decrease the amount of fuel injected, and also tends to retard the start of injection. A low nozzle opening pressure decreases the atomization of the fuel at low speeds, and in extreme cases will cause dribble. It also tends to increase the amount of fuel injected, which will cause a smoky exhaust from the engine cylinder affected. The best protection against trouble from this source is a periodic check of the nozzle or injector with the appropriate tester. One type of test stand is shown in fig. 2-41. Test stands will vary, depending upon the manufacturer, but all operate on the same principle. The type of test stand illustrated in figure 2-41 is intended primarily for activities doing a considerable amount of nozzle and injector reconditioning work.

Tests that may be performed on this type of fixture are: spray tip orifice test, valve opening pressure test, and holding pressure test. Complete details on test procedures should be obtained from the appropriate fuel injector equipment maintenance manual.

When a tester is used, keep in mind that the penetrating power of the fuel oil spray is sufficient to drive oil through your skin. Since this can cause blood poisoning, it is essential that all parts of the body be kept out of line of the fuel spray.

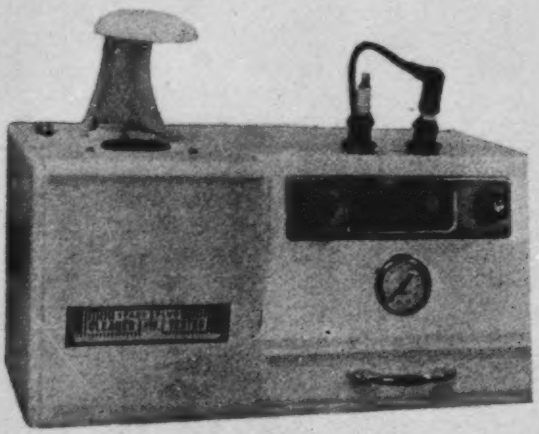
SPARK PLUG CLEANER AND TESTER

A spark plug cleaner (fig. 2-42) uses air and sand to sand blast the electrode or cylinder end of the plug free of carbon deposits and other undesirable material. A box-like cover encloses the cleaning and testing equipment. Air is connected to the cleaner part. This air blasts the sand against the plug to clean it. The plug must be rotated to insure all of the cylinder end is thoroughly cleaned. The plug should be cleaned with solvent and dried before using the sand blaster.

After cleaning, the plug and a new plug are screwed into the tester for comparison under pressure. The test comparison chamber has a small window with a mirror under it set at an angle so one can observe the spark jumping the electrodes. With the high-tension lead connected and the plug firing, the pressure is raised until the plug stops firing. Then the pressure is decreased until the plug fires steadily; at this point, a reading of the pressure is taken. The same procedure is repeated with the new plug and a comparison is reached.

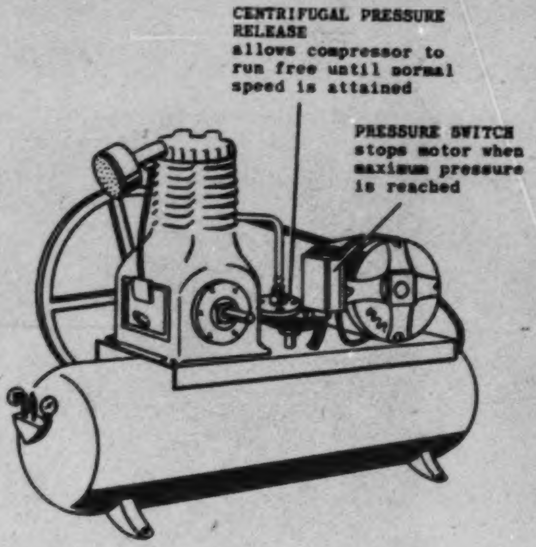
SHOP AIR COMPRESSOR

In an automotive repair shop, an air compressor is likely to be similar to the one shown in figure 2-43. The size of an air compressor depends on the number of air outlets required and the volume of air that is used. A compressor may be driven by an electric motor or by a gasoline engine. Permanent shops normally have electrically driven compressors. Temporary shops at advanced bases, where electric generating plants have not been set up, will have gasoline-driven compressors. A compressor driven by gasoline is usually placed outside the shop, and the air is piped in through a wall or window. This procedure helps to keep the noise and the exhaust gases from the engine out of the shop.



227.13

Figure 2-42.–Spark plug cleaner and tester.


CENTRIFUGAL PRESSURE RELEASE
allows compressor to run free until normal speed is attained
PRESSURE SWITCH
stops motor when maximum pressure is reached

227.14

Figure 2-43.–Shop air compressor.

A governor or automatic control is used on all shop compressors. It is usually adjusted to maintain a minimum pressure of 60 to 80 psi and a maximum pressure of 100 psi. The governor controls the switch of a compressor driven by an electric motor and the unloader valve of an engine-driven compressor.

LUBRICATING EQUIPMENT

Proper application of lubrication is one of the most important jobs you will do. It insures maximum equipment life at the lowest possible operating expense.

Two general kinds of lubrication equipment are in use: hand-operated and air-operated.

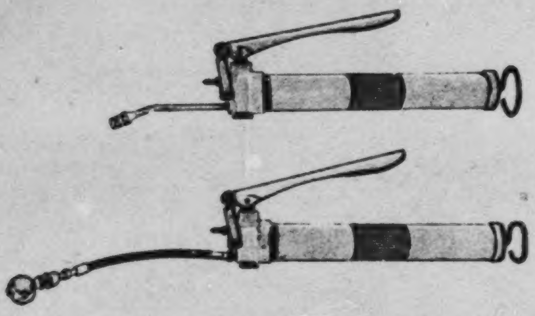


Figure 2-44.—Hand-operated grease guns.

Figure 2-44 shows some common types of hand operated grease guns. Nearly all pieces of heavy equipment have a hand-operated grease gun on them. The reason is that the operator must lubricate some of the fittings on the equipment daily. Hand grease guns are often used in temporary shops where compressed air is not available.

Nearly all permanent repair shops throughout the Navy have air-operated lubricating equipment. It may be either portable or stationary.

Figure 2-45 shows a permanent installation of lubricating equipment. High-pressure lines

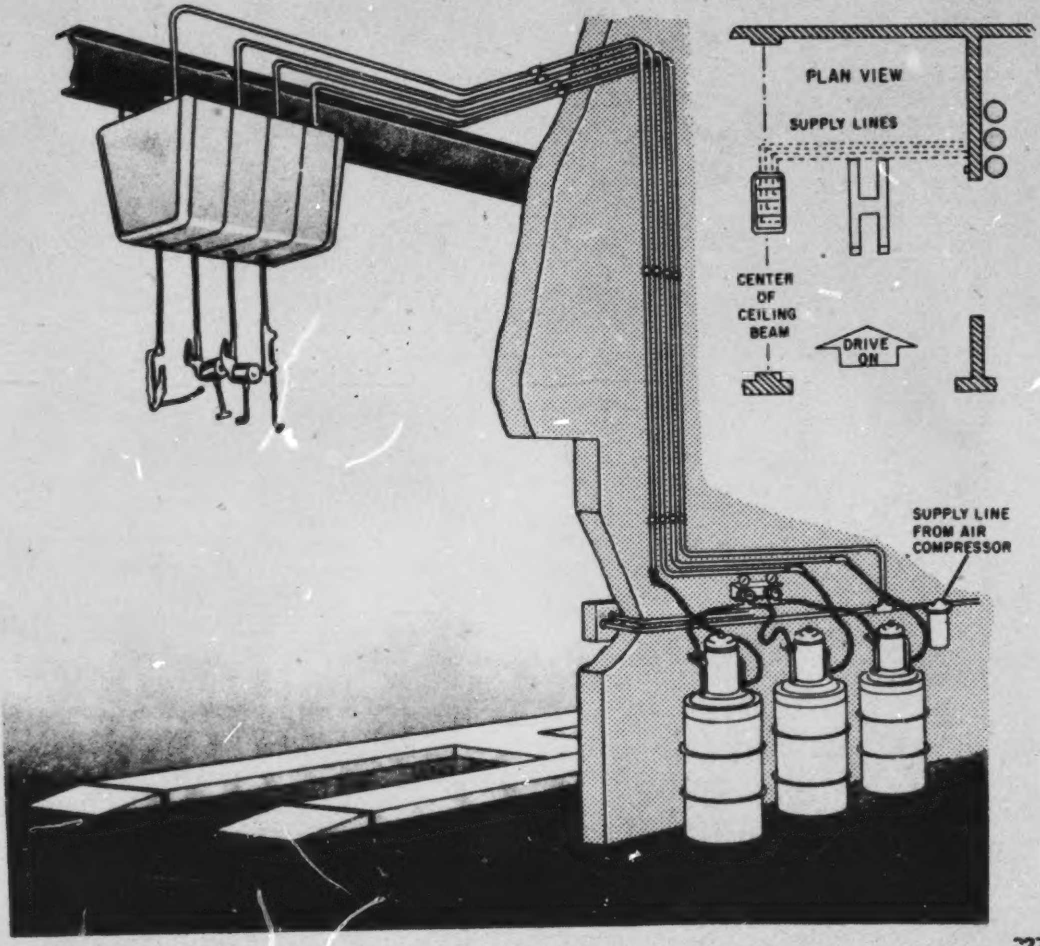

PLAN VIEW
SUPPLY LINES
CENTER OF CEILING BEAM
DRIVE ON
SUPPLY LINE FROM AIR COMPRESSOR
227.16

Figure 2-45.—Permanent installation of lubrication equipment.

carry the lubricants from containers to the lubricating guns. The guns are on hose reels that can be pulled from an overhead installation to any place on the vehicle. Notice in figure 2-45 that there are four outlets. These outlets handle chassis lubricant, automatic transmission fluid, gear lubricant, and air. The pumps, located on the lubricant containers, are air-operated. With an installation of this kind, the containers can be placed in some out-of-the-way place in the shop.

The portable lube units (fig. 2-46) may be air-operated, but the container and pump are mounted on casters and can be rolled to the job. The airhose connects directly to the pump with a quick connection. Some portable units are hand-operated with a lever action pump.

The volume pressure bucket pump is designed primarily for lubricating track roller bearings on equipment. Figure 2-47 shows a dual pressure volume pump. Switch the slot pin in the handle for high-pressure (approximately 5,000 psi) or low-pressure (approximately 2,000 psi) delivery. The container for this pump holds 40 pounds of lubricant and is filled through a large opening in the top. Both liquid lubricants

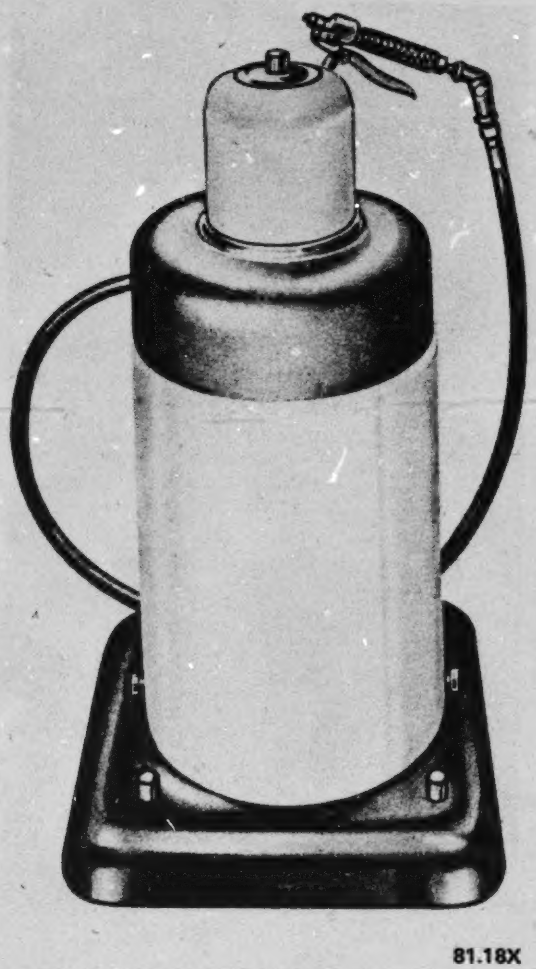

81.18X

Figure 2-46.–Portable air-operated lubricating equipment.

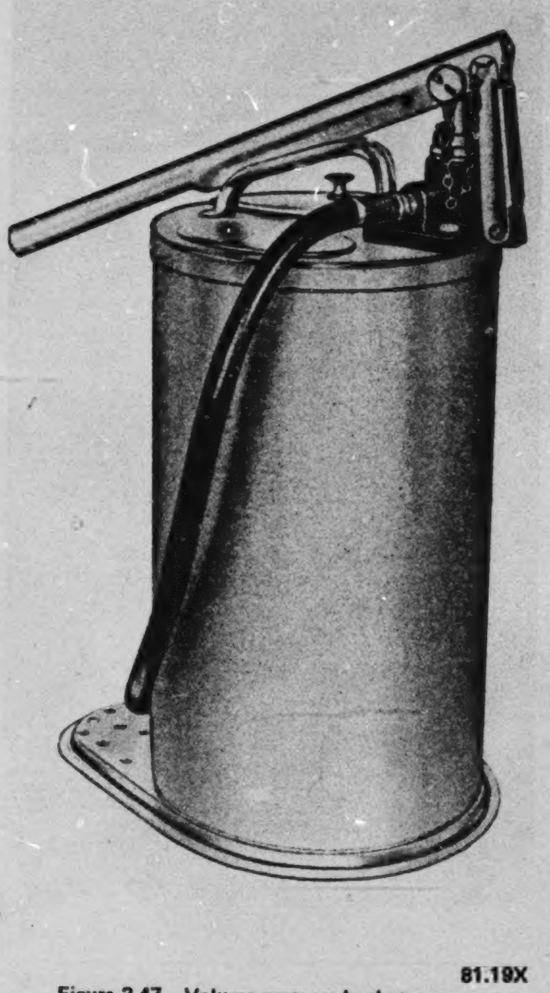

81.19X

Figure 2-47.–Volume pressure bucket pump.

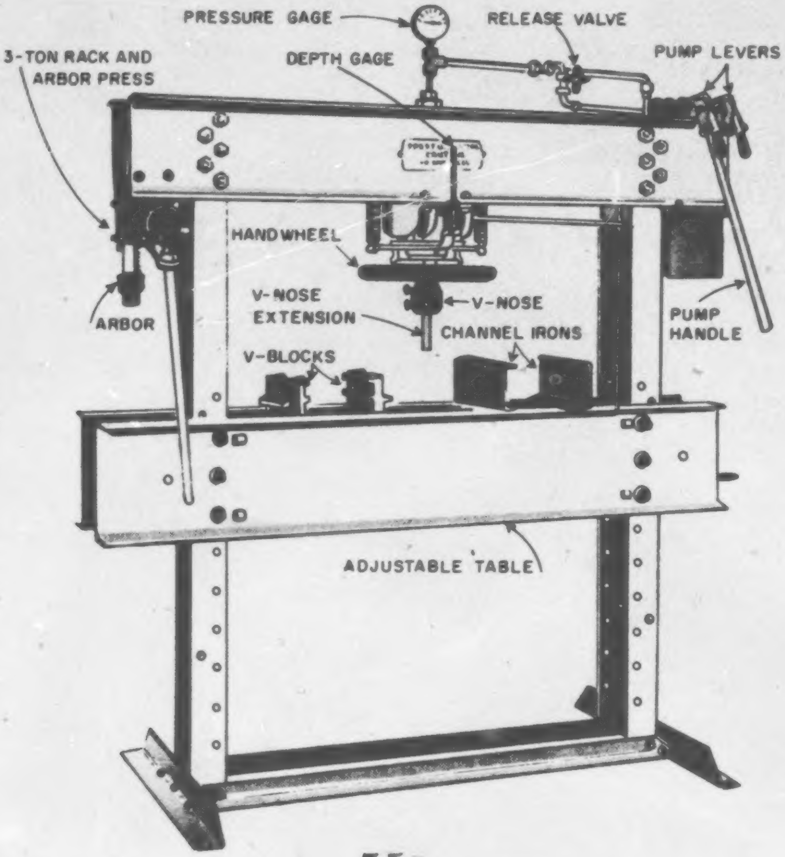
and heavy greases can be dispensed by most volume pressure bucket pumps.

Various nozzle extensions are available for both hand- and air-operated grease guns. By changing nozzles and extensions, all types of lubricating fittings can be serviced.

PRESSES

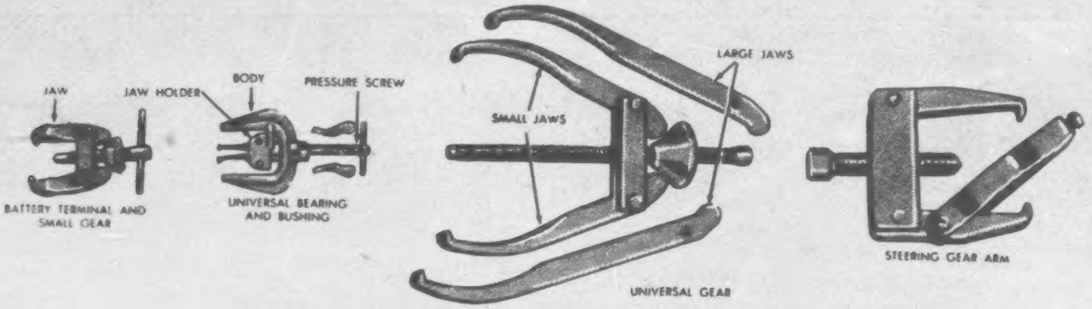
Presses are used for pressing bearings, bushings, gears, and other objects into and out of castings, or for other work which requires a large pressure in a concentrated area. Presses may be either gear, hydraulic- or air-operated. Most presses are mounted stationary to a bench or to the floor; consequently, all work must be brought to them.

The hydraulic press shown in figure 2-48 is a stationary floor-mounted model that will handle work requiring up to 60 tons of pressure. A gear-operated arbor press is located at the left side of the machine for work requiring not more than 3 tons pressure. The hydraulic press is controlled by a series of valves and levers, which are operated by hand. A pressure gage, mounted on top of the press, registers the amount of pressure applied to the work.


PRESSURE GAGE
RELEASE VALVE
3-TON RACK AND ARBOR PRESS
DEPTH GAGE
PUMP LEVERS
HANDWHEEL
V-NOSE EXTENSION
V-NOSE
ARBOR
PUMP HANDLE
CHANNEL IRONS
V-BLOCKS
ADJUSTABLE TABLE

81.24

Figure 2-48.—Hydraulic and arbor press.



81.27

Figure 2-49.–Bearing, bushing, and gear pullers.

PULLERS

Pullers are designed to facilitate pulling operations such as removing bearings, gears, wheels, pulleys, sheaves, bushings, cylinder sleeves, shafts, and other closefitting parts.

UNIVERSAL GEAR PULLERS (fig. 2-49) are usually of yoke and screw construction with two jaws. The jaws have from 0 to 14 inches diameter capacity, and have a reach from 3 to 16 inches.

UNIVERSAL BEARING AND BUSHING PULLER (fig. 2-49) has a pulling capacity of 1 1/4 inches. The larger jaws are designed to remove bronze or oilite bushings without crumbling them. The small jaws will clutch pilot bearings. The puller consists of a U-shaped body, a jaw holder, two large jaws, two small jaws, two jaw pins, and a pressure screw with slide bar.

BATTERY TERMINAL AND SMALL GEAR PULLER (fig. 2-49) is of the screw-type and is capable of use in close quarters. Besides pulling battery terminals, it is used to pull small gears, bearings, and so forth.

STEERING GEAR ARM PULLER (fig. 2-49) can also be used for a wide variety of jobs. The clamp locks the puller on the arm, leaving both hands free for the actual pulling operation.

PUSH AND PULL PULLER SET (fig. 2-50) is used in conjunction with a number of attachments and adapters. The push and pull puller consists of a 13 1/2-inch steel slotted bar to receive two legs. A pressure screw in the center of the bar is 13 inches long, having a diameter of 1 inch and threaded. This puller is universal and versatile with the use of bearing pulling attachment, bearing cup pulling attachment, sheave puller attachment, threaded adapters, step plate adapters, additional legs, and many other special adapters. This puller is capable of removing or replacing bearings, gears, pinions, pulleys, wheels, and bushings, and has many other uses.

A UNIVERSAL-TYPE STEERING WHEEL PULLER is shown in figure 2-51. The complete set consists of all the units necessary for removal of steering wheels from all cars and trucks from early models up to the present.

UNIVERSAL WHEEL PULLER SET (fig. 2-51) consists of a body and drive assembly that receives either three long jaws, three short jaws, or a special grooved hub set for Ford passenger cars. The interchangeable jaws pivot and swing to any desired bolt circle. Tapered, and right- and left-hand threaded stud nuts complete the set, all of which are carried in a metal case. It is capable of pulling any demountable wheel hub for any passenger car and most lightweight trucks. A chain-type wheel puller also is available that has a 1-ton pulling capacity (not illustrated).

UNIVERSAL CYLINDER SLEEVE PULLER (fig. 2-52) will pull the cylinder sleeves on more than 200 makes and models of trucks and tractors. It is adjustable to provide clearance regardless of the position of the cylinder studs and to simplify centering the tool over the bore. This puller is used in conjunction with four adapter plates supplied with the puller. The combination is capable of pulling cylinder sleeves 4 1/4, 4 1/2, 4 3/4, and 5 3/4 inches in diameter.

SLIDE HAMMER PULLER SET (fig. 2-53) is a universal-type puller equipped with a two- and three-way yoke, and three medium jaws for outside pulls and two small jaws for inside pulling. The small jaws can be inserted through a 1/2-inch opening. The capacity of the medium jaws is 2 1/4 inches. The slide hammer puller also is equipped with a locking feature which holds the jaws open or locks them on the work.

A COTTER PIN PULLER (fig. 2-53) is used to install or to remove cotter pins. It is an S-shaped tool, about 7 inches long. One end is inserted through the cotter pins for extracting, and the other end is used for spreading the cotter pin. The shank is beveled square for easy handling and firm grip.

Use of Pullers

Because pullers are used in nearly the same way regardless of whether they are to be used on engines, transmission, or chassis, some representative pulling situations will be explained in this chapter.

When using any puller, place it firmly in position and secure it if locking devices are part of the puller. Make certain the puller will not

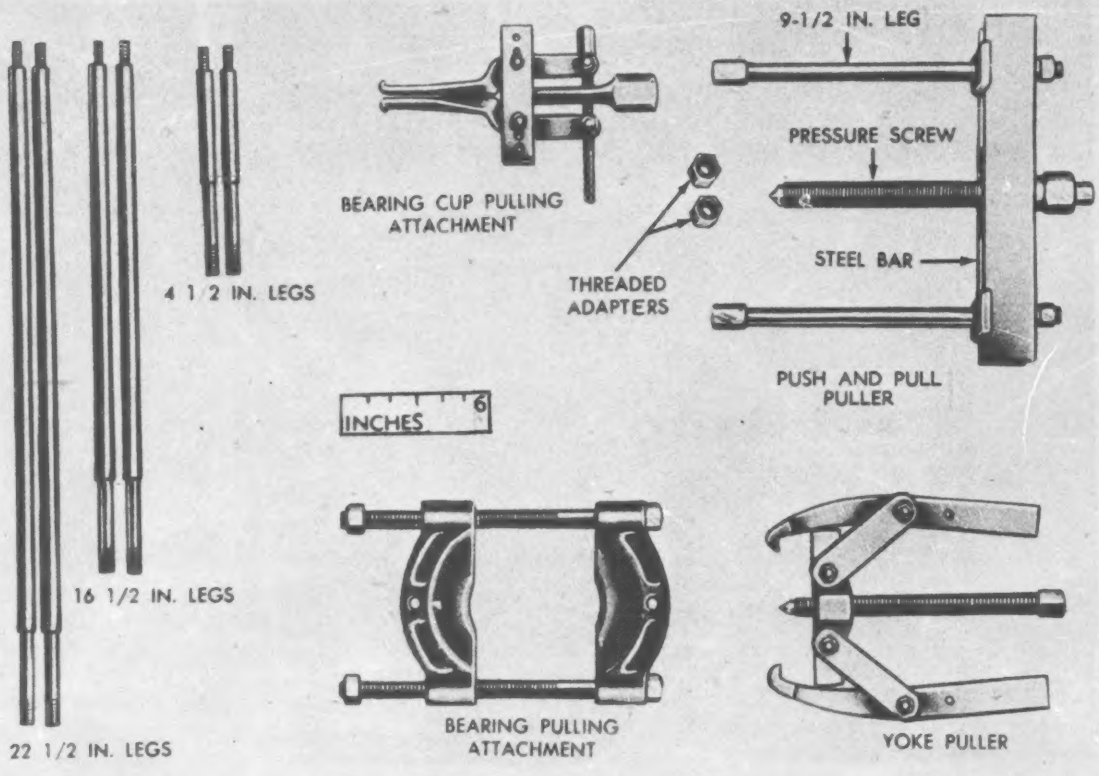

9-1/2 IN. LEG
PRESSURE SCREW
STEEL BAR
PUSH AND PULL PULLER
BEARING CUP PULLING ATTACHMENT
THREADED ADAPTERS
4 1/2 IN. LEGS
16 1/2 IN. LEGS
22 1/2 IN. LEGS
INCHES
6
BEARING PULLING ATTACHMENT
YOKE PULLER

Figure 2-50.—Push and pull puller set.

81.28

slip off suddenly while under strain. Check all gripping edges and threads of a puller for damage before using it. Use the proper size wrench for turning the pressure screw or nut to avoid rounding the corners of the nut or of the screwhead. Use the proper size puller for the job.

The universal push and puller set is probably the best all-around puller combination available. Several combinations of its components are discussed and illustrated.

Figure 2-54 shows a combination of the push and pull puller and the bearing cup pulling attachment used to remove a bearing cup from a cage. The same combination is used to install it back in the cage, as shown in figure 2-55.

To pull a camshaft gear, use the push and pull puller with 9 1/2-inch legs with two

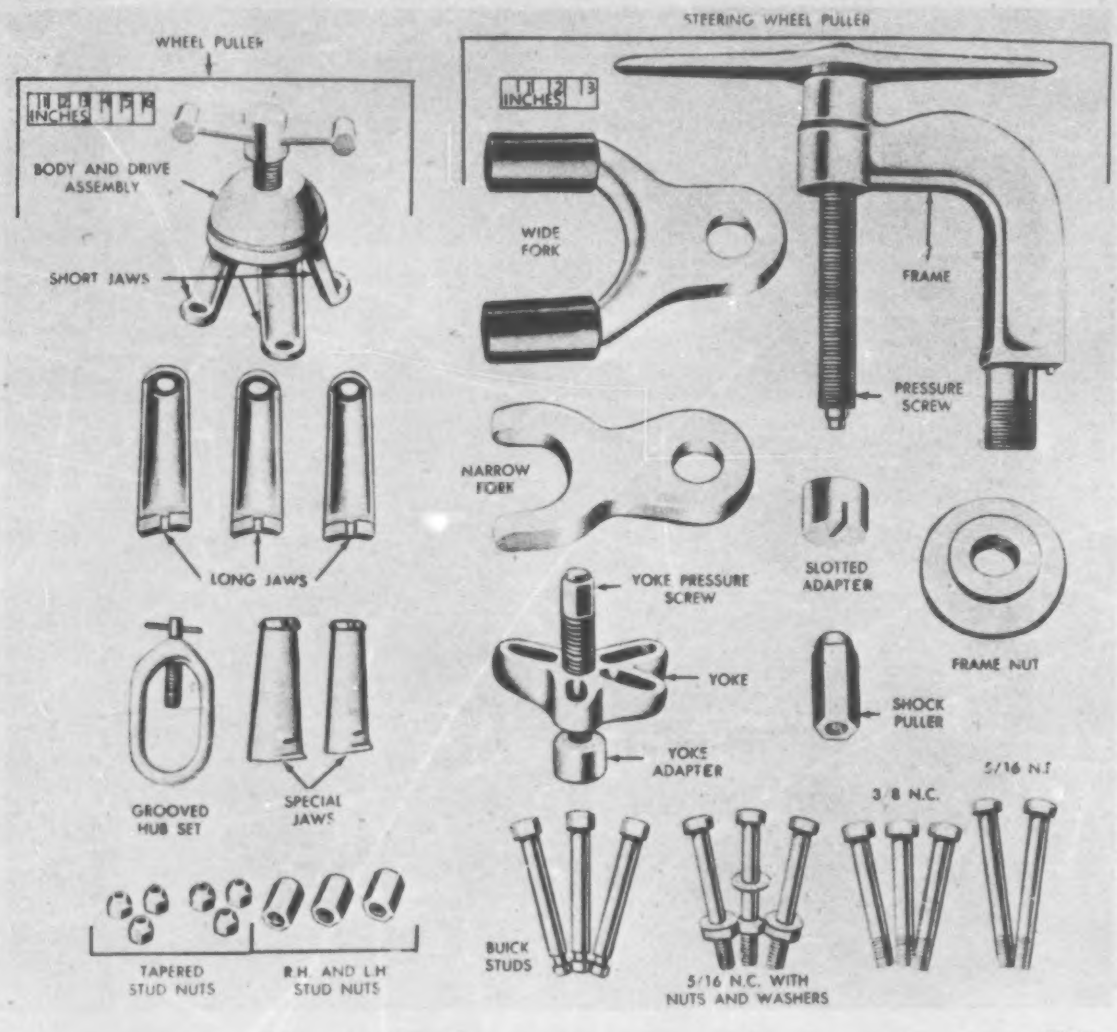
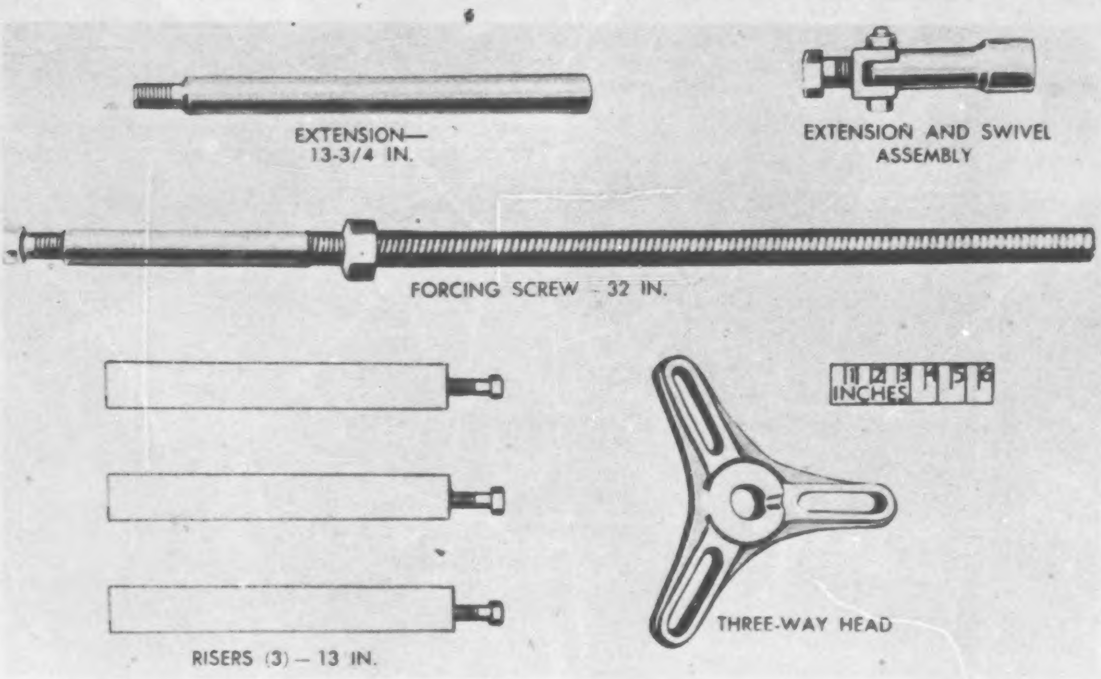
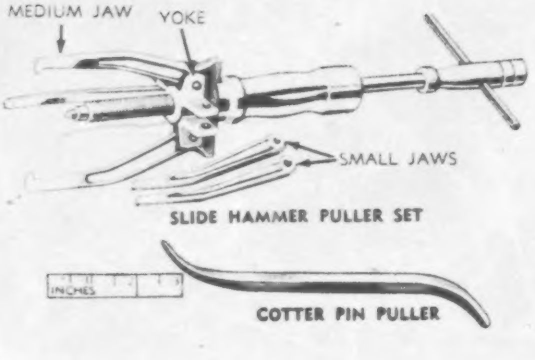

WHEEL PULLER
INCHES
BODY AND DRIVE ASSEMBLY
SHORT JAWS
LONG JAWS
GROOVED HUB SET
SPECIAL JAWS
TAPERED STUD NUTS
R.H. AND L.H STUD NUTS
STEERING WHEEL PULLER
INCHES
WIDE FORK
FRAME
PRESSURE SCREW
NARROW FORK
SLOTTED ADAPTER
FRAME NUT
YOKE PRESSURE SCREW
YOKE
YOKE ADAPTER
SHOCK PULLER
3/8 N.C.
5/16 N.F.
BUICK STUDS
5/16 N.C. WITH NUTS AND WASHERS

Figure 2-51.—Steering wheel and wheel pullers. 81.29


EXTENSION—
13-3/4 IN.
EXTENSION AND SWIVEL ASSEMBLY
FORCING SCREW - 32 IN.
INCHES
RISERS (3) — 13 IN.
THREE-WAY HEAD

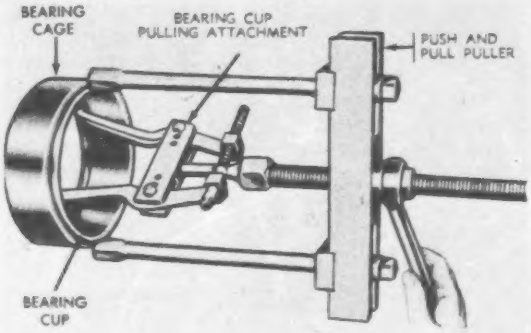
81.30

Figure 2-52.—Cylinder sleeve puller.


MEDIUM JAW
YOKE
SMALL JAWS
SLIDE HAMMER PULLER SET
INCHES
COTTER PIN PULLER

81.31

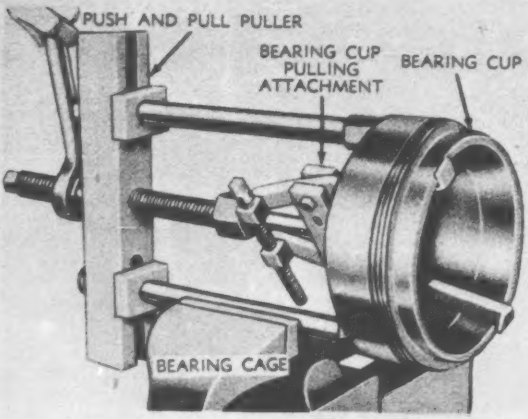
Figure 2-53.—Slide hammer puller set and cotter pin puller.


BEARING CAGE
BEARING CUP PULLING ATTACHMENT
PUSH AND PULL PULLER
BEARING CUP

81.32

Figure 2-54.—Removing bearing cup.

adapters as shown in figure 2-56. Here the camshaft gear is being removed without removing the camshaft from the engine. A protective plate should be used under the forcing screw to protect the end of the camshaft.

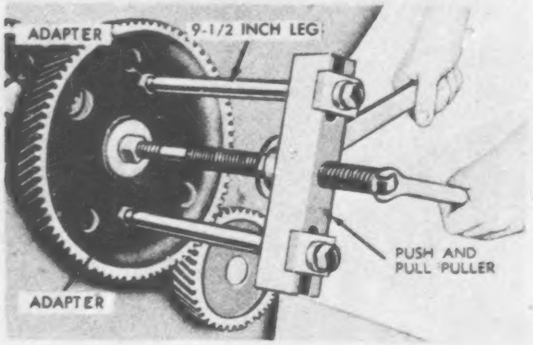

PUSH AND PULL PULLER
BEARING CUP PULLING ATTACHMENT
BEARING CUP
BEARING CAGE

81.33

Figure 2-55.–Installing bearing cup.

Figure 2-57 illustrates the use of the bearing pulling attachment and a pair of forcing bolts used to remove a bevel pinion shaft from a transmission case. The forcing bolts bear against the case and force the pinion shaft out. Tighten forcing bolts alternately to obtain a uniform even pull to prevent cocking.

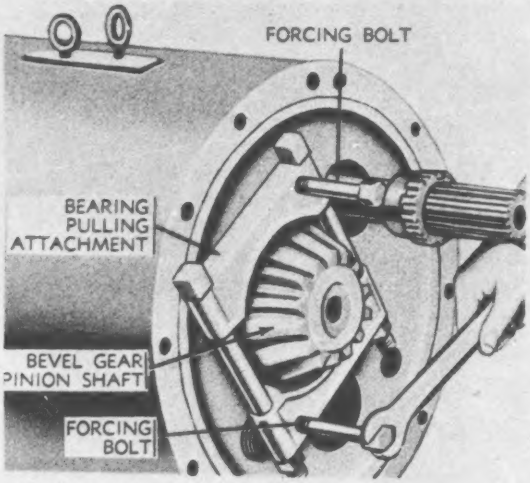
In figure 2-58 a roller bearing assembly is being removed from a transmission shaft with a combination of the bearing pulling attachment and the push and pull puller.


ADAPTER
9-1/2 INCH LEG
PUSH AND PULL PULLER
ADAPTER

81.34

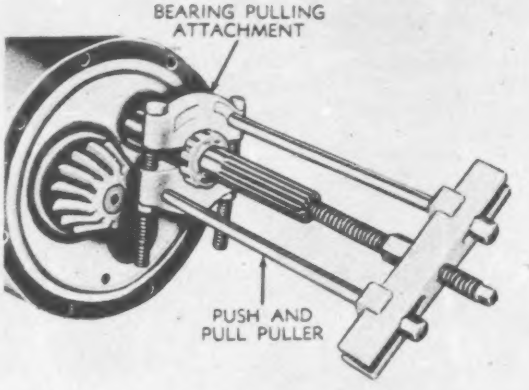
Figure 2-56.–Pulling a camshaft gear.

The steering wheel puller set (fig. 2-51) handles the job of pulling the steering wheels on all cars and trucks. The yoke puller and its related parts are used to pull the newer models, since they have tapped wheel hubs. The fork puller and its related parts are used on older models. The pressure screw in the frame puller is


FORCING BOLT
BEARING PULLING ATTACHMENT
BEVEL GEAR PINION SHAFT
FORCING BOLT

81.35

Figure 2-57.–Pulling a bevel gear pinion shaft.

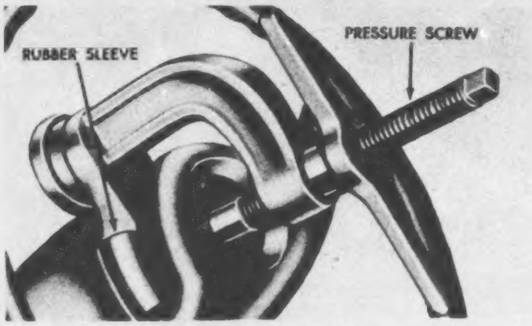

BEARING PULLING ATTACHMENT
PUSH AND PULL PULLER

81.36

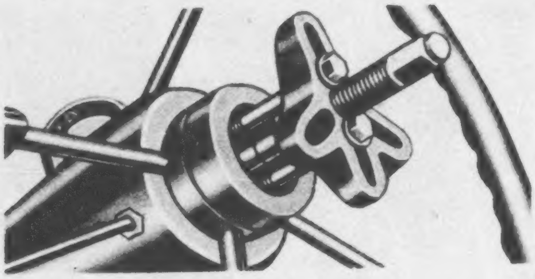
Figure 2-58.–Pulling a bearing.

threaded its entire length and works through a key. The narrow fork has a brass insert and the wide fork has rubber sleeves to protect the steering column. Adapters protect the shaft from damage. Figure 2-59 illustrates the use of the wide fork and frame puller on older type hubs and the yoke puller removing a late model steering wheel.

The cylinder sleeve puller (fig. 2-52) is adjustable to provide clearance regardless of the number or position of the cylinder head studs, and to accurately center the tool over the bore (fig. 2-60). Four adapter plates are supplied with the puller set which cover sleeves from 4 1/4 to 5 3/4 inches in diameter. The adapter is positioned so that the cylinder sleeve rests on the edges of the adapter. The puller swivel assembly is inserted from the top and screwed into the adapter. By tightening the forcing screw, a steady force is applied which will pull the sleeve out of the cylinder.



A – WIDE FORK AND FRAME USED ON OLDER TYPE HUBS



B – YOKE AND SCREW ASSEMBLY USED ON LATE MODEL HUBS

81.37

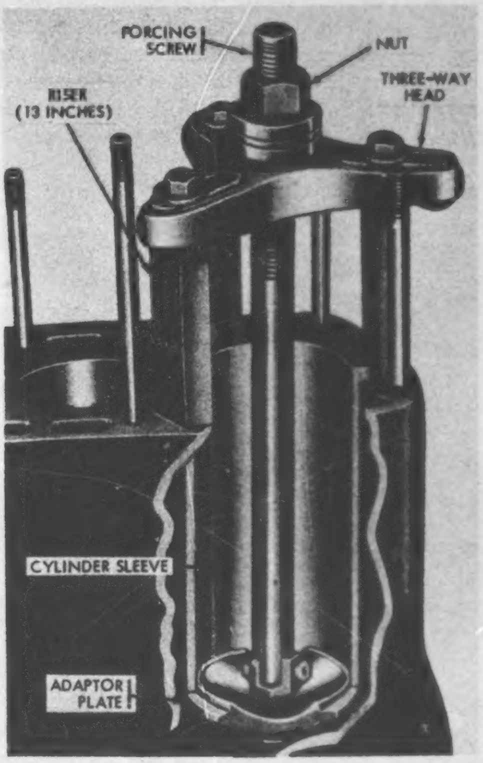
Figure 2-59.–Using steering wheel puller set.

Care of Pullers

Keep pullers clean at all times. Grease or oil on the gripping edges will make the tool slip. Clean all pullers after use and store them so that the threads and gripping edges will not become damaged. Make certain all attachments and adapters are stored with the basic puller and do not become separated.

SPECIFICATIONS

In your work around the shop, you will often hear the term "specifications" or "specs." Specifications refer to the measurements of the parts of a vehicle. For instance, an automobile manufacturer's shop manual may specify that the piston-ring gap should be .002 inch, or that intake valve stem to bore clearance should be .001 to .003 inch.



81.38

Figure 2-60.–Using a cylinder sleeve puller.

When you notice that a measurement is off, you will usually have to make an adjustment or repair. Always consult the shop manual applicable to each vehicle to obtain the manufacturer's specifications.

POWER TOOLS

Power tools are very useful to the mechanic and lighten his work by using electricity and air to perform fatiguing and time-consuming jobs. These electric and pneumatic tools include impact wrenches–used to tighten or loosen nuts, bolts, and screws, and drills–used to drill holes in wood or metal. These power tools and other power tools are covered in Part I, Section 2 of *Tools and Their Uses,* NAVPERS 10085 (Series).

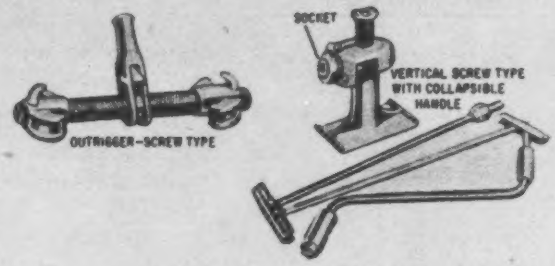
LIFTING DEVICES

JACKS

Jacks are used to raise or lower heavy loads short distances. Some jacks are used for pushing and pulling operations, or for spreading and clamping.

Jacks are available in capacities from 1 1/2 to 100 tons. Small capacity jacks are generally operated through a rack bar or screw, while those of large capacity are usually operated hydraulically.

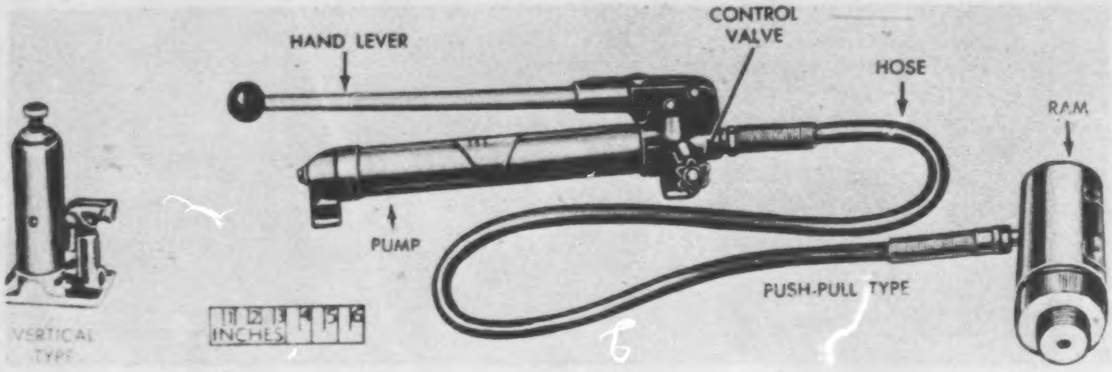
The vertical screw jack (fig. 2-61) is operated by hand through a collapsible handle which is inserted in a socket. The screw moves up or down, depending on the direction of rotation in which the handle is turned. Some of these jacks are equipped with a ratchet for automatic lowering. Mechanical screwjacks come in several capacities having different contracted and extended heights. Another type of screwjack is called an outrigger jack. It is equipped with end fittings which permit pulling parts together or pushing them apart.



81.25

Figure 2-61.–Mechanical screwjacks.

A vertical hydraulic jack (fig. 2-62) operates through pressure applied to one side of a hydraulic cylinder which moves the jackhead. These jacks are automatically lowered or released by releasing the pressure. Vertical hydraulic jacks come in different capacities from 3 to 100 tons and have different extended heights.



81.26

Figure 2-62.–Hydraulic jacks.

A push-pull hydraulic jack (fig. 2-62) consists of a pump and ram connected by a hydraulic or oil hose. Jacks of this type are rated at 2-, 7-, 20-, 30-, and 100-ton capacities and have diversified applications.

The vertical jacks are used to lift one side of or the end of a vehicle to permit removal of the wheel or tires or to effect repairs that would not be possible with the vehicle standing on its wheels. The jack can be used on each side alternately by jacking one side of the vehicle up, then blocking it and moving the jack to the other side, and then continuing this operation until the vehicle has been raised to the desired height.

Jacks may also be used to raise heavy crates, small buildings, or other items too heavy to be raised by prying with wrecking bars. It is essential that the jack be placed on solid ground or on planks to spread the weight so that it will not give way or tip when being used.

The push-pull hydraulic jacks are furnished with an assortment of attachments that enable you to perform countless pushing, pulling, lifting, pressing, bending, spreading, and clamping operations. The pump is hand-operated. Simply turn the control valve on the side of the pump clockwise, stroke the hand lever up and down, and the ram will extend. The flexible hydraulic hose allows you to operate the ram in any desired position and from a safe distance. The ram retracts automatically by turning the control valve counterclockwise.

Keep fingers away from all moving parts when jacking up vehicles and make certain no one is under the vehicle to be raised. Place blocking or other supports under the vehicle when it is raised to the desired height to prevent it from dropping if the jack fails. Before using them, make certain that hydraulic jacks are filled with oil and that there are no visible oil leaks.

CHAIN HOIST

Chain hoists provide a convenient means for hoisting heavy objects. When a chain hoist is used, the load can remain stationary without requiring attention. The slow lifting travel is especially advantageous when removing an engine from a vehicle. It permits small movements, accurate adjustments of height, and cautious handling of loads.

Chain hoists differ widely in their mechanical advantage, depending upon their rated capacity. Three types generally used for vertical hoisting operations are the differential chain hoist, the spur gear hoist, and the screw gear hoist.

The SPUR GEAR HOIST (fig. 2-63) is best for ordinary operations that require frequent use of a hoist and where a minimum number of men are available to operate it. The spur gear hoist is about 85 percent efficient. In other words, about 85 percent of the energy exerted by you is converted into useful work for lifting the load. The remaining 15 percent of the energy is spent in overcoming friction in the gears, bearings, chains, and so forth.

The SCREW GEAR HOIST is often satisfactory in operations that require less frequent use of a hoist. This type of hoist is about 50 percent efficient. The DIFFERENTIAL HOIST is suitable for light loads and where only occasional use of the hoist is involved. This hoist is only about 35 percent efficient.

The load capacity of a chain hoist is stamped on the shell of the upper block. The rated load capacity of hoists runs from 1/2 ton upward.

The lower hook is usually the weakest part in the assembly of a chain hoist. This is intended as a safety measure so that the hook will start to spread open if overloaded. Thus, close observance is necessary to detect any sign of overloading in time to prevent damage.

Before using a chain hoist, inspect it to insure safe operation. A hook that shows signs of spreading or excessive wear should be replaced. If links in the chain are distorted, the chain hoist has probably been overloaded. In any case, make sure the hoist is in good repair before attempting to lift a load.

Always be sure the chain hoist is suspended from a support that will support the load you are going to lift. Also insure that the method of fastening the chain hoist to the support is adequate.

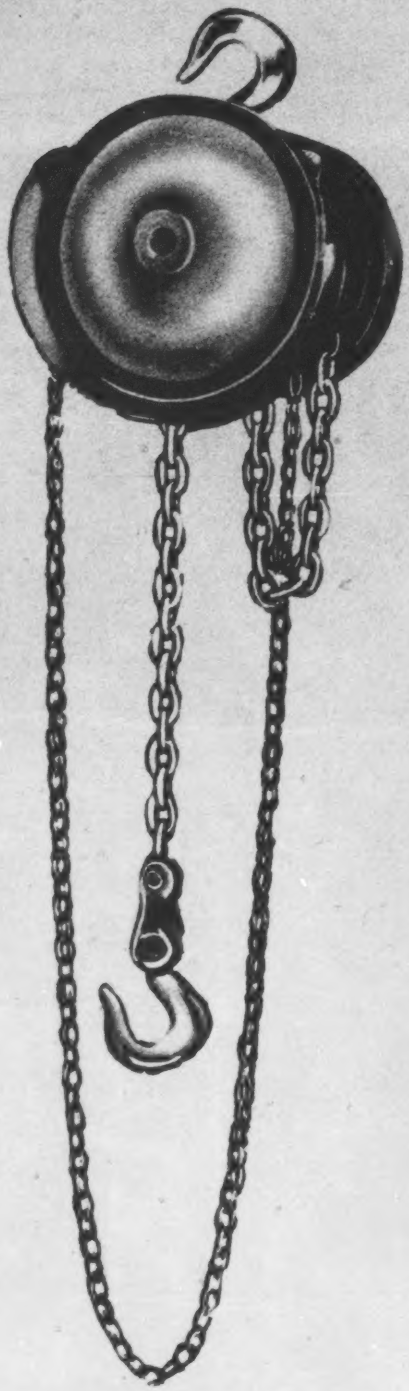


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Figure 2-63.–Spur gear chain hoist.

BLOCK AND TACKLE

The use of block and tackle is explained in chapter 2 of *Basic Machines*, NAVPERS 10624 (Series). When using block and tackle to remove an engine or lift a heavy load be sure the rope and the blocks are in good condition and heavy enough to lift the proposed load. Provision must be made to tie the rope to an object heavy enough to hold the load lifted if it is desired to hold the load stationary for any length of time. Tension on the rope or blocks should not be maintained for long periods as the rope may be permanently damaged.

SHOP PRACTICE AND SAFETY

WORKING WITH TOOLS

The practices followed in a shop with respect to work habits and safety largely determine how effectively the shop operates. Tools and equipment can never be more efficient than the person using them. As a petty officer, remember that you are responsible not only for your own safety and work habits, but also for the men assigned to you.

When you are assigned a job, lay out beforehand the handtools to be used. Work quietly and give full attention to the work. Do not scatter tools about, and keep them out of aisle spaces where they might be stumbled over. Keep your tools clean; always wipe off any grease or dirt after using them. Use the proper tools for each job; never fall into the habit of using a tool for a job for which it was not intended.

Misuse of tools may damage them or the equipment you are working on and may cause injury to you or to others. Exercise great care when working with power-driven tools and machines. Keep hands away from rotating parts of a machine, and always shut off a machine when it is necessary to make any adjustment to the work on the machine, or to the machine itself.

SAFETY

Personal safety in shop work cannot be over-emphasized. A few points on safety have been mentioned in the previous section. The following additional points are particularly important.

Wear gloves, goggles, and other protective devices as the job requires. Because of the danger of flying particles, it is especially important to wear goggles when you are grinding or are using compressed air.

When you are repairing vehicles, block them with sturdy wooden timbers. If you are using jacks or hoists, be sure that they center or support the vehicle properly. Critical, or even fatal, injuries, as well as badly damaged vehicles, can result from the improper use of hoisting and jacking equipment.

Be extremely careful when working around gasoline. Repair any vehicle which is leaking gasoline as soon as possible, and do not start the vehicle engine until the leak is corrected. Use only spark-proof tools when you are working on gasoline lines.

If gasoline or other flammable liquid is spilled on the shop floor, cover the spots with sweeping compound and let the compound absorb the liquid before sweeping it up. If you must wipe up gasoline, always discard the cloth or rags that you use. Put them in containers with lids in order to guard against spontaneous combustion.

If there is a strong odor of gasoline in the shop, turn on an exhaust fan or throw open all doors and windows. Gasoline vapors can be ignited from a spark or by static electricity. Keep all gasoline containers sealed when they are not in use.

All portable power tools should be carefully inspected before using to insure that they are clean and in the proper state of repair. On electrically driven tools the switches should operate normally, cords should be defect-free, and the tool should be properly grounded. When preparing to use any power tool lay out the cord, hose, or cable so it will not be run over or constitute a tripping hazard or come in contact with a sharp object. Do not allow any kinks to form. Power tool cords, hoses, and cables should not be permitted to come in contact with oil, grease, hot surfaces, or chemicals. When damaged they should be replaced, not patched with tape.

Some powered tools use compressed air for power. Compressed air must be classified as a possible hazard. Workers have received eye injuries because an airhose caused dust to be blown into their eyes with enough force to cause serious damage. When connecting the airhose to the tool, be sure the hose is firmly locked to the tool. Always use goggles over the eyes when using compressed air for cleaning or drying a part. A jet of compressed air striking the exposed body, from close range, can cause serious bruises and possibly internal hemorrhaging. Use compressed air only for its intended purpose.

Unless the shop has areas marked off for smoking, do not smoke while on duty in the shop. Even if shop policy does allow smoking in restricted areas, it is better to do your smoking outdoors, if weather permits.

Your shop will have a list of safety regulations posted. Study these regulations until you are thoroughly familiar with them.

The safety practice of keeping tools in good working condition and using the correct tool for the job cannot be overemphasized. When you see a mechanic with many nicks, scratches, cuts, and/or bruises on his hands, you are looking at a careless worker. Train yourself to eliminate carelessness and to be a cautious worker. By replacing each tool in the proper place in the toolbox when finished with it you can determine that all tools have been returned to the toolbox from the last job by taking a quick check of the toolbox. This is necessary to prevent loose tools from being left in or around the engine where they can cause considerable damage and can become a safety hazard.

CHAPTER 3

AVIATION SUPPORT EQUIPMENT

Ground support equipment has become as important to the assigned mission of naval aviation activities as the aircraft itself. Many different types of support equipment are required for handling, servicing, loading, testing, and maintaining aircraft. The majority of this equipment is utilized in direct support of the aircraft; therefore, the aircraft squadron is one of its principal users. Another principal user of certain types of support equipment is the Air Department aboard aircraft carriers. Within this department, personnel of the flight deck and hangar deck aircraft handling crews utilize such aircraft handling equipment as tow tractors and spotting dollies. In addition, personnel of the Aircraft Crash, Fire, and Rescue crews utilize such equipment as the MB-5 aircraft firefighting and rescue truck. These users depend upon personnel of the Aviation Support Equipment Technician rating, who are normally assigned to Intermediate maintenance activities, for the maintenance of this equipment.

Support equipment is usually operated by personnel of the using activity. Since such activities as aircraft squadrons and carrier Air Departments are the principal users, the equipment is usually operated by personnel of ratings other than AS. In addition, maintenance such as servicing and performing preoperational inspections, is frequently accomplished by personnel of these using activities. Thus, the AS rating is concerned primarily with major inspections and repair. However, this does not mean that personnel of the AS rating are relieved of all responsibilities concerning the operation and servicing of the equipment. In fact, the ASM as well as the ASE and ASH, should be experts in these procedures. To effectively perform all phases of maintenance—inspecting, troubleshooting, repairing, testing, etc.—the ASM must understand thoroughly the operation of the equipment. This is especially important when troubleshooting malfunctions and testing equipment.

In addition, the ASM is frequently called upon to check out squadron personnel in the operation and servicing of certain types of equipment. Several types of support equipment require licensed operators. The procedures for training, testing, and licensing of these operators are also responsibilities of the Aviation Support Equipment Technician rating.

Obviously, it is impossible to relate detailed operating procedures for all types of support equipment in the scope of this training manual. Examples are given on some of the equipment described in this chapter. It must be emphasized, however, that this is a training manual for support equipment in general and that the applicable Operation and Service Instructions for a specific item of equipment must be consulted for the correct operating and servicing procedures.

TYPES OF GROUND SUPPORT EQUIPMENT

For the purpose of maintenance functions and responsibilities, ground support equipment is classified into five major categories.

1. Avionics support equipment.
2. Gasoline, electric, and diesel powered servicing equipment.

3. Gas turbine powered servicing equipment.
4. Trailers, dollies, and carts (nonpowered).
5. Miscellaneous support equipment.

The first category, avionics support equipment, pertains to the equipment required to maintain and test avionic systems and components. The maintenance of this equipment is assigned to PME repair and AIMD or DEPOT level maintenance activities. With the exception of a few items of equipment, the remaining four categories are the maintenance responsibility of the AS rating and are described in the following sections.

GASOLINE, ELECTRIC, AND DIESEL POWERED SERVICING EQUIPMENT

This category includes those types of support equipment which are powered with diesel or gasoline driven engines or with electricity. (This category does not include turbine powered equipment.) Such equipment as tow tractors, weapons loaders, mobile electric power-plants, air conditioners, hydraulic test stands, air compressors, and steam cleaners are included in this category. Some representative types of powered servicing equipment are described in the following paragraphs.

Tow Tractors

The tow tractor is the only means of propulsion for the majority of aircraft when the aircraft is on the ground and the engines are not running. Most present day aircraft are too heavy and large to be moved by manpower alone. Tow tractors are also used for towing trailer-mounted support equipment.

Tow tractors must be especially maneuverable, particularly those used on aircraft carriers. Maneuverability of the tractor depends on its dimensions and turning radius. The smaller the dimensions and turning radius the more maneuverable the tractor will be. The type of transmission may also contribute to the ease of handling of the tractor. Modern tow tractors are usually equipped with automatic transmissions. Compared with the standard transmission, the automatic transmission provides a smoother coupling from the engine to the driving wheels. It also frees the driver from operating a clutch and allows him to concentrate more on the job at hand. This results in smoother and safer movement of aircraft and equipment.

Tow tractors are often rated by drawbar pull. The drawbar pull is the amount of force that the tractor can exert. The drawbar pull of any tractor is dependent on the type and condition of the surface on which it is being used. Dry concrete gives the most traction; hence the most drawbar pull for a given tractor. On a wet, fuel-soaked steel deck the traction may be almost nil.

Support equipment for supplying electric power and/or compressed air for aircraft engine starting or servicing is installed on some tractors.

Tow tractors are usually classified by one of two designations—the M series and the TA series. Some tractors may have both designations. The first two letters of the M series do not have a standard meaning. The number in the M series is the model number. A letter following the model number indicates the number of modifications to that model tractor. An A indicates the first modification, a B indicates the second modification, etc. The TA in the TA series denotes Tractor Aircraft. The numbers following the TA indicate the first two numbers of the drawbar pull. Other designations are sometimes used to identify tractors. One example is the JG-75 tow tractor. This tractor, however, is one model of the TA-75A or TA-75B which is discussed later.

All tractors classified as a certain type are not always manufactured by the same contractor. As a result, the tractors may not be identical in all respects. They may differ in appearance. The instruments and control may be arranged differently. Such major components as the engines and transmissions may be manufactured by different companies. However, these tractors are still classified as the same type as long as they meet the Military Specifications for that type. The same is true for many other types of support equipment. This is another important reason why all personnel of the AS rating should consult the applicable technical publications to properly and safely operate, service, and maintain each specific item of support equipment.

As indicated by the preceding discussion, there are several types and models of tractors available to aviation activities. The tractors described in the following paragraphs are representative of the types most widely used at the present time.

TA-18 TOW TRACTOR.—This is a gasoline powered tractor for use on shore bases as an aircraft towing and spotting vehicle for large aircraft. This tractor has a drawbar pull of 18,000 pounds.

The TA-18, shown in figure 3-1, has an automatic transmission with 6 forward speeds and 1 reverse [illegible] The speed ranges are selected by a shift [illegible] located on top of the transmission cover. The transmission shift pattern is shown in figure 3-2. The tractor dimensions are 14 feet 10 inches long, 8 feet wide, and 5 feet 7 inches high. The turning radius is 24 feet 10 inches. The gross weight of this tractor is 25,800 pounds. Normally, the driver's compartment is open, as shown in figure 3-1; but if the tractor is to be used in cold weather, it can be obtained with a completely enclosed cab. These cabs are equipped with windshield wipers, heater, and defroster.

TA-75A TOW TRACTOR.—The TA-75A is a gasoline-powered tractor intended for use on shore bases as a towing and spotting vehicle for aircraft with gross weights up to 75,000 pounds.

The TA-75A (fig. 3-1) has provisions for mounting a gas turbine compressor or other servicing equipment. It is equipped with an automatic transmission that has three forward speeds and one reverse speed. The tractor dimensions are 20'3" long, 5'6" wide, and 3'2" high. The turning radius is a minimum of 140"

MRS-190 TOW TRACTOR.—The MRS-190 tow tractor (fig. 3-1) is intended for use at air stations for positioning aircraft arresting gear. This tractor weighs 47,000 pounds and is capable of exerting sufficient drawbar pull to perform practically any work that may be required. It is 17 feet long and 9 feet 6 inches wide. It is powered by a 355-horsepower diesel engine and is equipped with a 5-speed standard transmission.

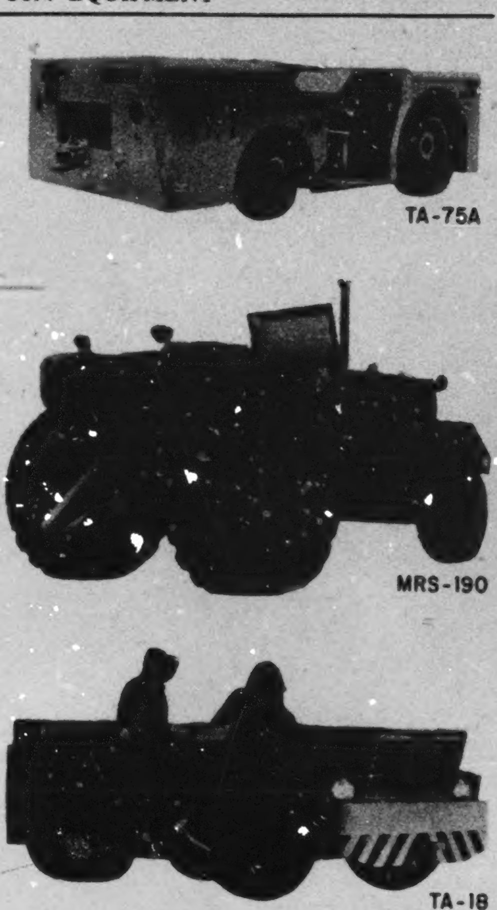

Figure 3-1.—Tow tractors.

MD-3 TOW TRACTOR.—This tractor was designed for use aboard aircraft carriers and will handle any type of carrier-based aircraft. It can be configured as an MD-3 (basic tractor—no gas turbine power unit), MD-3A (mounts a GTCP-100-54 gas turbine power unit), or MD-3B (mounts a GTC-85-72/73 power unit). The MD-3A is shown in figure 3-3.

The MD-3 tow tractor is a self-contained unit capable of developing 8,500 pounds

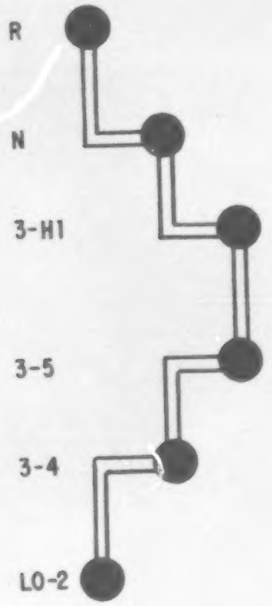

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Figure 3-2.—TA-18 transmission shift pattern

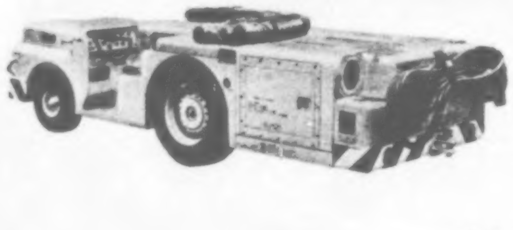

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Figure 3-3.—MD-3 tow tractor.

drawbar pull at an approximate speed of 1 mph on a dry, level concrete surface. The main powerplant of this type tractor is an inline horizontal, four-stroke cycle, internal combustion diesel engine. The steering system is hydraulically assisted, and the service brakes are assisted by compressed air. The gross weight of the MD-3 tractor is 12,000 pounds.

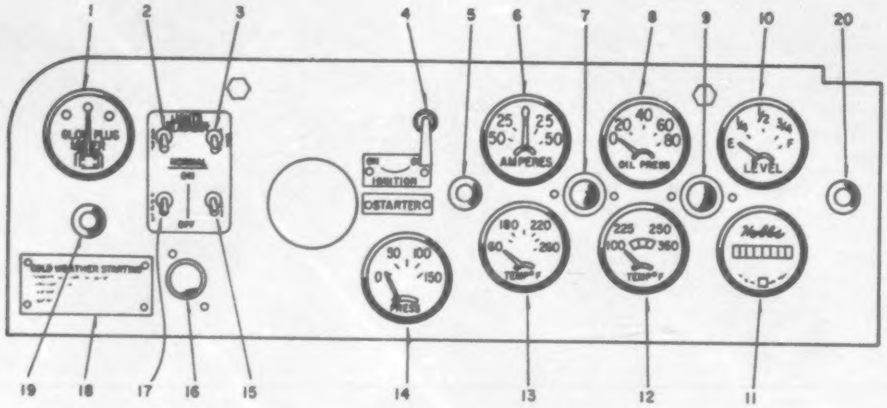
The transmission is a multiple reduction drive unit that shifts automatically in all forward gear ratios. It is bolted to the engine bell housing and is driven through a single-stage torque converter. A hydraulic control system regulates the transmission shifts. The system also synchronizes the engagement and release of the control clutches and brake bands to effect quick position shifts to meet load demands. The complete transmission system is lubricated, operated, and cooled by a single oil system.

A gas turbine compressor mounted at the rear of the tractor provides pneumatic power in the form of compressed air for the operation of large class pneumatic equipment, such as aircraft main engine starters, and other consumers of compressed air. The operating controls for the gas turbine compresser are located on a panel on the right-hand side of the operator's compartment. Compressor operation is outlined on two instruction plates adjacent to the controls.

The ASM is required to operate the tractors when training personnel, in troubleshooting, and in testing after repairs have been made. Therefore, he must be familiar with the different instruments and controls. Figure 3-4 shows the instrument/control panel, and figure 3-5 shows other controls of an MD-3 tractor.

OPERATION OF TOW TRACTORS.—The ASM is required to operate tractors when training personnel, troubleshooting malfunctions, and testing after repairs have been made. As mentioned previously, the operating procedures relative to the various types and models of tow tractors differ in some respects. The operation of the MD-3 is used as a representative example in the following discussion. It should be emphasized that the current applicable Operation Instructions should be consulted for the correct operating procedures relative to the different types and models of tow tractors.

Before attempting to operate any type of equipment, the operator should be familiar with the different instruments and controls. Figure 3-4 shows the arrangement of the instruments and controls, and figure 3-5 shows other controls of one model MD-3 tow tractor.

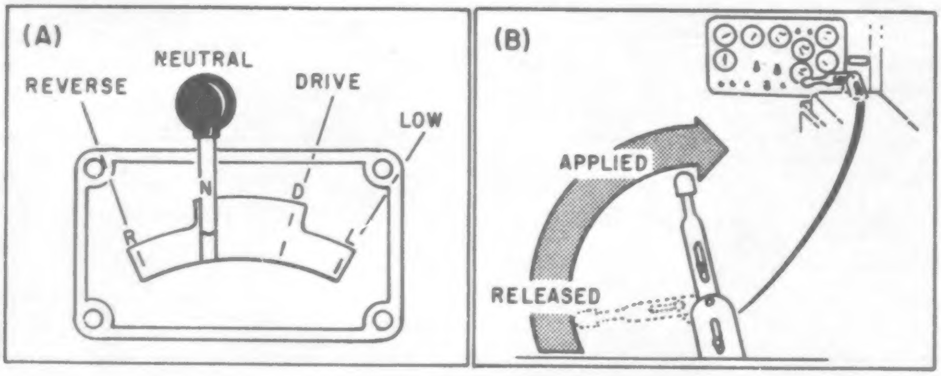

1
2
3
4
5
6
7
8
9
10
20
GLOW PLUG METER
AMPERES
OIL PRESS
LEVEL
IGNITION
STARTER
NORMAL
OFF
COLD WEATHER STARTING
PRESS
TEMP °F
TEMP °F
19
18
17
16
15
14
13
12
11

AS.672

1. Glow plug meter.
2. Stoplight switch.
3. Headlight switch.
4. Ignition switch.
5. Start switch.
6. Ammeter.
7. Dash lamp.
8. Engine oil pressure gage.
9. Dash lamp.
10. Fuel gage.
11. Hourmeter.
12. Torque converter temperature gage.
13. Engine temperature gage.
14. Air pressure gage.
15. Instrument Light Switch.
16. Air low-pressure warning light.
17. Pintle light switch.
18. Instruction plate.
19. Glow plug switch.
20. Horn button.

226.5

Figure 3-4.—MD-3 instrument/control panel.


(A)
NEUTRAL
REVERSE
DRIVE
LOW
N
R
D
L
(B)
APPLIED
RELEASED

225.214

Figure 3-5.—MD controls. (A) Shift pattern;
(B) parking brake lever operation.

Procedures for starting the MD-3 tractor depend on weather conditions. If the average ambient temperature is above 40° F, NORMAL starting procedures should be followed. If the average temperature is 40° F or below, COLD WEATHER starting procedures should be followed.

The normal starting procedures are as follows:

1. Apply the hand brake and shift transmission to N (neutral). (See fig. 3-5.)
2. Turn the ignition switch (item 4, fig. 3-4) ON and push the starter button (5) until the engine begines firing regularly. Should the engine fail to start immediately, release the starter button and allow a 2-minute recovery time before making additional attempts to start. Excessive engine cranking at any one time may damage the cranking motor.
3. After the engine starts, check the engine oil pressure (8), water temperature (13), and the operation of the ammeter (6). The ammeter should indicate a positive (+) charging rate.

CAUTION: Stop the engine if there is a sudden rise in engine temperature and/or no oil pressure.

The diesel engine of the MD-3 is equipped with glow plugs for cold weather starting. A glow plug is an electrical heating element installed next to each fuel injector and is used to preheat the injector and combustion chamber. The heating element is supplied with current from the battery. To complete this electrical circuit, the ignition switch (4) and the glow plug switch (19) must be ON. Operation of the glow plug is indicated on the glow plug meter (1). Normal gage operation is indicated by the gage pointer moving to the far right when the glow plug switch is pressed.

Cold weather starting procedures are as follows:

Table 3-1.—Glow plug preheating chart

Ambient Air temperature °F	Preheating time (minute)
60	0.5
30	1.0
0	1.5
-20	3.0

1. Apply the hand brake and shift the transmission lever to N (neutral).
2. Turn the ignition switch (4) ON and press the glow plug switch (19) to preheat the engine combustion chambers. Allow the amount of preheat time as indicated in table 3-1. After the combustion chambers have been warmed, press the starter button. Do not release the glow plug switch until the engine begins firing regularly.
3. If the engine fails to start during the first 30 seconds of cranking, release the starter button to allow a 1-minute recovery period before making additional attempts at starting. Do not release the glow plug switch between start attempts.
4. After the engine starts, run it at a fast idle until the engine oil pressure gage (8) indicates oil circulation and the engine temperature gage (13) indicates that the cooling system is warm. Idle the engine until full air pressure is developed in the brake system. This is indicated by the air pressure gage (14) and the air low-pressure warning light (16). The warning light is on whenever pressure in the air system is less than 60 psi. The tractor should not be operated until the warning light is OFF and the air pressure gage indicates more than 60 psi.

CAUTION: Do not use glow plugs while the tractor is working. Damage to the engine may result.

To operate the tractor, apply the service brakes and release the parking brake. (See fig. 3-5 (B).) With the engine idling, select the type transmission operation desired with the shift lever. (See view (A), fig. 3-5.) Release pressure on the brake pedal and gradually increase the accelerator feed to start moving the tractor. The transmission should be operated in the following manner.

All normal forward driving and towing with light or moderate loads should be accomplished with the shift lever at D. In this position the transmission will automatically upshift and downshift between second gear and third gear (direct drive). Maximum acceleration is obtained by fully depressing the accelerator, causing the transmission to automatically downshift from third gear to second gear. When pressure on the accelerator is decreased, the transmission will automatically upshift.

The shift lever should be moved to L when the tractor is used to tow near maximum loads (8,500 pounds drawbar pull), ascend steep grades or pull through sand, mud, or snow. In addition, engine braking power can be gained when the transmission is in this gear ratio. This braking power assists the braking action of the service brakes, The transmission will not upshift automatically from first gear while the lever remains at the L position.

The shift lever may be moved from L to D or from D to L at any tractor speed. If the shift lever is at D when the tractor is at a standstill and the accelerator is fully depressed, the transmission will automatically downshift from second gear to first gear. As tractor and engine speed increases, the transmission will automatically shift from first gear through second to third gear.

The tractor must be brought to a complete stop before making the shift between D and R. When the tractor must be rocked back and forth, maintain a steady but moderate pressure on the accelerator pedal and move the shift lever back and forth between D and R.

During tractor operation, the operator should listen for unusual sounds which may indicate trouble. Gages and instruments should be checked periodically. Any unusual gage indications, such as excessive temperatures or pressures, are warnings of possible troubles. For example, the torque converter temperature gage (item 12, fig. 3-4) shows the temperature of oil leaving the converter. Readings will vary with working conditions, but the converter temperature should never exceed 250° F.

TOW BARS

Two general classes of tow bars are used in naval aviation; those adaptable to only one type

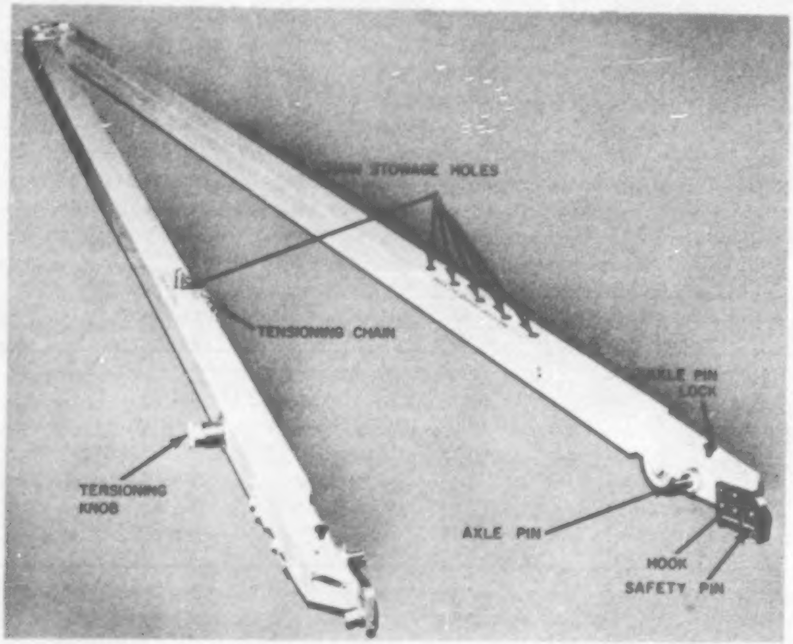


Figure 3-6.—Universal front and rear tow bar. 199.18.1

of aircraft, and those adaptable to more than one type of aircraft. Most naval aircraft may be towed with the Universal Aircraft Tow Bar, Model NT-4, shown in figure 3-6. The tubing of this tow bar is made of aluminum alloy. The tow hitch plate, end hooks used in forward towing, and the pins that fit into the hollow axle of the tailwheel and nosewheel are made of steel. The aluminum wheel well casting is bushed to take the towing pins when changing from nosewheel to tailwheel towing and vice versa.

For forward towing of aircraft not having a nosewheel, the end hooks of the tow bar are placed through the main landing gear towing rings. The hooks are held in place by spring-loaded lockpins. When towing aft from the hollow axle of the tailwheel, the towing pins on the wheel well casting are placed in the tailwheel axle on each side. They are then clamped in place by a chain that slides through a sleeve and is tensioned by turning a knob. A similar procedure is used in towing certain aircraft from the nosewheel; however, the towing pins are removed from the wheel wells and reversed. On other aircraft with this type of landing gear, the end hooks of the tow bar are placed through the towing rings of the nosewheel and locked in place by the spring-loaded lockpins provided for this purpose.

Certain aircraft may be satisfactorily towed only by the use of a tow bar designed specifically for them. For the proper use of such tow bars, consult the manufacturer's instructions for that particular aircraft.

CHOCKS

The Navy universal wheel chock (Model MWC-2), is used to immobilize aircraft aboard carriers and to some extent on shore stations. (See fig. 3-7.) This is an all-metal chock that is adjustable to fit landing gear wheels up to 45 inches in diameter. Other types of chocks are used ashore and are usually locally fabricated of wood or wood and line.

TIEDOWNS

The TD-1A all-purpose tiedown (fig. 3-8) is the one most commonly used by the Navy for securing parked aircraft. The ease and speed with which it can be attached to or removed from an aircraft make it most desirable during flight operations aboard carriers when time is vital.

MOBILE CRANES

Mobile cranes are used both at shore stations and aboard ship. Those for shipboard use are usually smaller and to some degree more maneuverable than shore-based cranes. The mobile crane is an emergency vehicle primarily designed for use in aircraft salvage and rescue.

Maximum performance of the mobile crane, including its operating equipment, is dependent

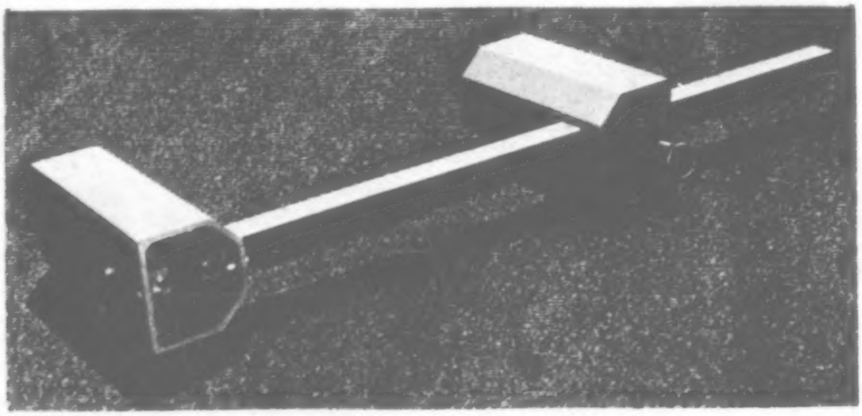
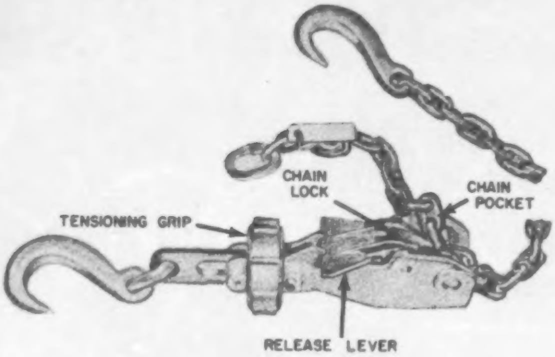


Figure 3-7.—Universal wheel chock. 199.14.1



199.16

Figure 3-8.—All-purpose tiedown.

upon the frequency and scope of the maintenance rendered plus the ability of the operator to properly operate the crane. Personnel must be thoroughly familiar with the contents of the applicable technical manual before attempting to operate a crane.

The NS-50 and NS-60 Mobile Cranes are designed primarily to lift and carry crashed aircraft on the flight deck of an aircraft carrier, and are equally suitable for similar duty on shore stations for both aircraft landing areas or unpaved areas. The NS-50 and NS-60 are quite similar in appearance and in operation, the basic difference being in the greater length of the boom and lifting capacity of the NS-60. For purpose of discussion, the NS-50 is described in the following paragraphs. The NS-50 is illustrated in figure 3-9.

This crane, a self-propelled vehicle, is mounted on four electrically powered wheels. Heavy-duty dc electric traction motors and gear reduction units built within the wheel rims provide motive power for the crane. Each wheel motor is equipped with multiple-disc spring-loaded brakes for emergency stops and parking, while a regenerated electrical braking system is used for operational deceleration of the crane.

Gear motors power the boom, hook, and steering. AC electric motors, strategically located at the point of power application, drive through gearboxes to power each crane function. Each ac motor is equipped with a multiple disc, spring-loaded brake that sets instantly when the motor's electrical power is interrupted. Restoration of the motor's electrical power automatically releases the motor brake.

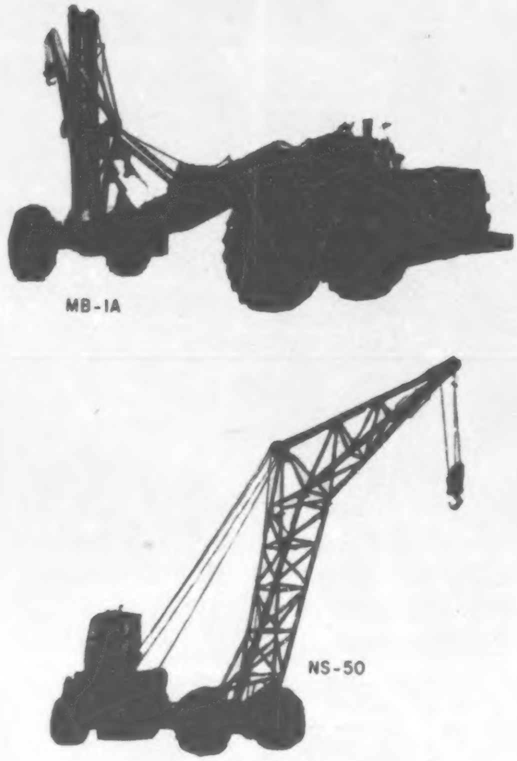


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Figure 3-9.—Mobile cranes.

AC and dc generators, directly coupled to the diesel engine, supply current to the control motors and to the dc drive motors. Fingertip switches on the operator's panel control the application of power to the ac motors. One control handle on the panel provides power and directional control to the electric wheels, while another gives the operator complete motor braking control.

All normal operations required for maneuverability of the crane are managed from the operator's station. A remote control panel on the rear of the crane permits control of the hook and boom at a point near the load.

The crane is 40 feet long without the boom. With the boom extended 23 feet, the overall length is 64 feet 9 inches. The overall height is 33 feet with the boom extended. The turning radius is 35 feet. The gross weight of the crane is 72,300 pounds.

The crane is capable of lifting 50,000 pounds when its boom is positioned anywhere between its minimum and 23-foot outreach. The crane is also capable of exerting a drawbar pull of 42,000 pounds for towing operations.

MB-1A Mobile Crane

The MB-1A mobile crane (fig. 3-9) is designed primarily for lifting, maneuvering, and removing crashed aircraft from air station runways and surrounding areas. The MB-1A is made up of a 2-wheel vehicle (prime mover) attached to a 2-wheel crane.

The prime mover is powered by a diesel engine driving through a twin-disc clutch, a 5-speed transmission, a high/low speed auxiliary transmission, and a torque-proportioning differential. The auxiliary transmission, in combination with the 5-speed transmission, results in 10 speeds forward and 2 speeds in reverse. The wheels of the crane are not powered.

An ac generator, driven from the engine flywheel, supplies current for powering the hook motor, jib motor, boom motor, and the steering motor. These motors are controlled by fingertip switches located at the operator's station. A remote control box is provided for controlling the hook, jib, and boom motors from a position near the point of pickup.

Air brakes are provided on all four wheels. These brakes consist of alternate discs splined to the brake drum and brake hub. Air pressure directed to a pressure plate forces the discs together for braking. Springs are used to move the pressure plate to the release position when air is bled from the brake. Selector valves are provided to control the selection of front, rear, or both brake sets. There are three stations where a sound-powered telephone may be used. One set is used in the cab by the operator, and the other may be used at the left side of the crane tongue or at the rear of the crane. To use, plug in the phone jack at the station outlets.

MOBILE ELECTRICAL POWER PLANTS

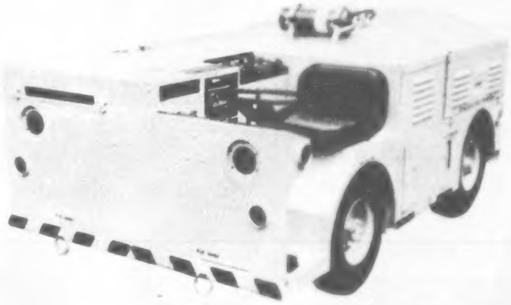
Mobile electrical powerplants (MEPPs) supply electrical power for various testing and checkout operations of aircraft. The MEPPs used today are designed for operation on shore stations and aboard aircraft carriers. On aircraft carriers these units are usually of the mobile type, with minimum vehicular dimensions and weight; they are usually designed for utmost maneuverability and mobility. On shore stations, these units may be mobile, large in size, or may be trailer-mounted and require towing.

There are many types of MEPPs in use. The type used depends upon the type of aircraft to be serviced. Three of the various types of MEPPs are described briefly in the following paragraphs.

NC-2A Powerplant

The NC-2A (fig. 3-10) is designed primarily for emergency use aboard aircraft carriers. (Normally, deckedge power is used.) It is a self-propelled diesel-engine-powered service unit. It is front-axle-driven, steered by the two rear wheels, and readily maneuverable in congested areas. The front axle is driven by a 28-volt dc, reversible, variable speed motor, capable of propelling the unit up to 14 mph on level terrain, and has a turning radius of 130 inches.

The primary source of power is a 3-cylinder, water-cooled diesel engine which drives the ac



225.118

Figure 3-10.—MEPP NC-2A.

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and dc generators through a speed increasing transmission. All controls, both propulsion and electrical power, are available to the operator on three panels located in front and to the right of the operator's seat.

The powerplant is designed for air transport and is provided with two tiedown rings each on the front and rear bumpers. Forklift channels are located between the front and rear axles, providing safe lifting points for the unit.

NC-8A Powerplant

The NC-8A (Fig. 3-11) is a mobile, self-propelled, diesel-engine-powered service unit which is utilized for starting and servicing rotary and fixed wing aircraft. It is capable of providing 400-hertz, 3-phase, 120/208 vac, 60-kva power, and 500 amperes (current limited) intermittent power.

The NC-8A mobile electric powerplant consists of a four-wheel, front-steering, electric-motor-propelled vehicle, a dual voltage ac/dc generator, and a water-cooled, four-cylinder, two-stroke-cycle diesel engine.

The powerplant is designed for air transport and is provided with four tiedown rings, two each on the front and rear bumpers. Forklift channels are located between the front and rear axles, providing safe lifting points for the unit.

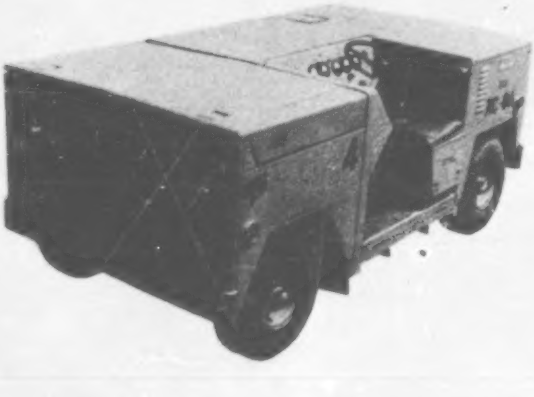

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Figure 3-11.–NC-8A Mobile Powerplant, Front 3/4 view.

NC-10B Powerplant

The NC-10B (Fig. 3-12) is a diesel-engine-driven unit designed for shipboard or shore station use. This unit supplies 90-kva, 120/208-volt, 3-phase, 400-Hz power for servicing, starting, and maintaining helicopters and jet aircraft. A portion of the electrical power generated is rectified to supply 28 volts dc at 750 amperes, (1,000 amperes intermittent) for aircraft starting.

The powerplant is enclosed in a steel housing, fabricated in two sections which are easily removed for servicing the unit. Operating components are mounted on a four-wheel trailer which is equipped with mechanical type internal expanding wheel brakes. The brakes may be set by hand lever, and set automatically when the tow bar is in the vertical position.

Double hinged doors provide access to the control panel, starting components, and three output power cables.

The plant's electrical system is protected from overload by output circuit contactors, circuit breakers, over-voltage and undervoltage relays, overfrequency and under-frequency relays, thermal overload relays, and fuses.

The unit is self-propelled, for movement between aircraft on the line, by two hydraulic wheel motors. The operator's control is located on the towbar. Hydraulic pressure is supplied by the hydraulic system which also provides pressure to operate the engine starter and the electrohydraulic governor's actuator system.

MOTOR GENERATOR ASSEMBLIES

Motor generator assemblies supply low voltage and high-power current required for aircraft servicing and component testing. Some motor generator assemblies supply dc power only, and others furnish dc and ac power. Most assemblies are portable.

The ATE-105 uses ac current that operates a motor. This motor drives a dc generator that supplies current for use in servicing and testing of aircraft components. The CDM-15 has an ac

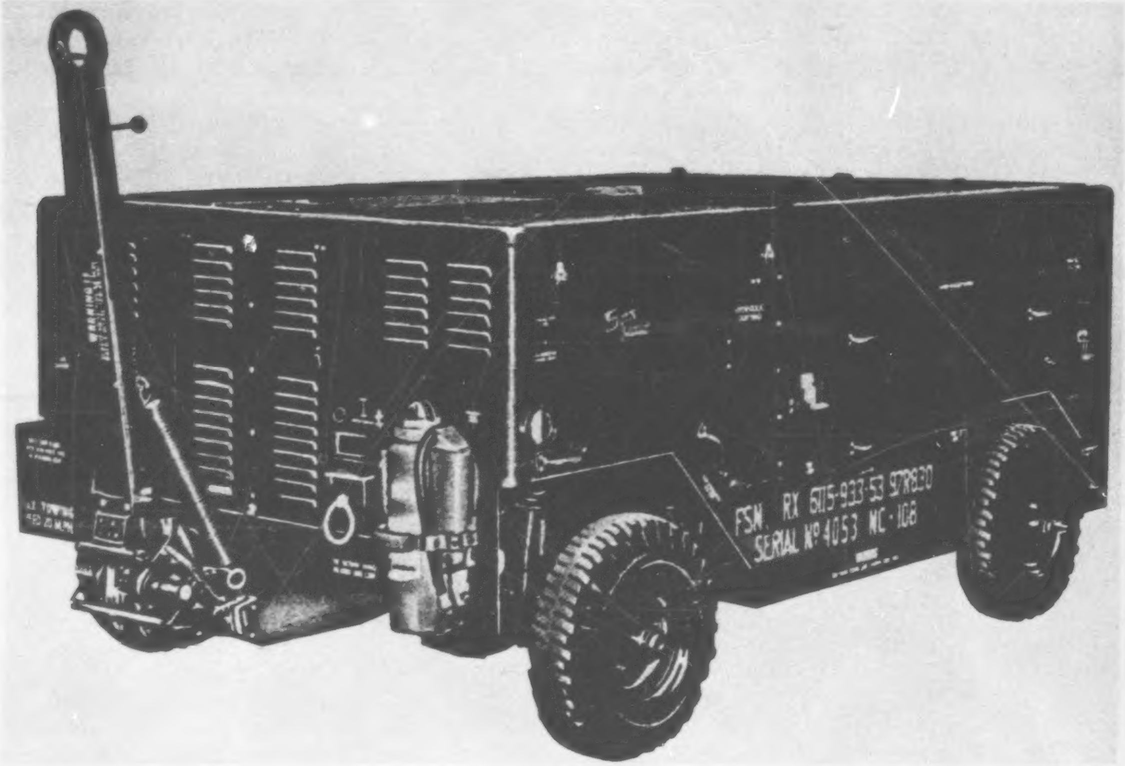

Figure 3-12.—MEPP NC-10B. 225.137

motor that drives a dc and ac generator for use on aircraft maintenance. Both of these motor generation assemblies are plugged into hangar or shipboard outlets and generate the type of current needed to service Navy aircraft. The ASE will have the responsibility of maintaining these units.

FORKLIFT TRUCK

The forklift truck is a much used, powerdriven piece of material handling equipment. It is a cantilever type of industrial truck, either diesel, gasoline or electrically operated, having either three or four wheels. It contains vertical uprights and an elevator backplate equipped with two or more forks of sufficient length and thickness for use with various types of pallets. (See fig. 3-13.) Forklift trucks that come under the care of the ASM are powered by diesel and gasoline engines and have pneumatic or solid rubber tires. Forklift trucks are generally used to handle palletized unit loads but may also be used to haul boxes or containers equipped with skids, as well as other large containers and packages. They are used to hoist heavy loads into aircraft. They are also used to move loads aboard carriers, on barges, on piers, in warehouses, and in and around freight terminals.

The forklift truck must be operated only by a licensed operator. The servicing and upkeep are similar to those required for any automotive equipment.

PREHEATERS AND AIR CONDITIONERS

Preheaters and air conditioners are used in maintaining desired temperatures in aircraft on

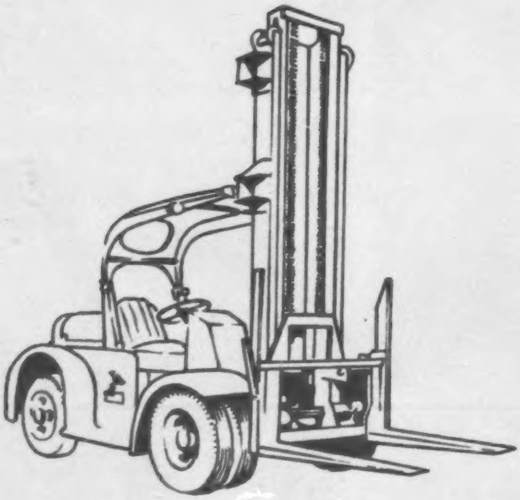

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Figure 3-13.—Forklift truck.

the ground. In the following paragraphs, an example of each type of unit is discussed.

PREHEATERS

The NPH-3 portable preheater produces up to 1 million BTU per hour of heat for ground heating of aircraft, portable shelters, or any space requiring heat. It is a box-shaped, four-wheeled, towed vehicle that has expanding-type parking brakes on the rear wheels. It is powered by a two-cylinder, air-cooled engine developing 13.6 horsepower. This engine drives a ventilating air blower and a generator. The blower forces air through the heater and through the outlet ducts. The generator actuates the spark plug to ignite the combustible mixture in the combustion chamber of the heater. The heater burns the same gasoline as the engine. Twin outlet ducts can supply heat through 30 feet of 12-inch ducts.

AIR CONDITIONERS

Air-conditioning units are designed to provide ground ventilating and cooling for aircraft cabins and electronic systems. Most units will perform the following functions:

1. Cool aircraft avionics equipment compartments.
2. Ventilate equipment compartments at ambient temperatures where cooling is not required.
3. Cool occupied aircraft cabins.
4. Cool pressurized personnel suits.

Air-conditioning units are usually trailer-mounted. The unit is usually powered by either a gasoline or diesel engine, or electric motors. Air-conditioning units are identified by the letter designation NR, followed by a model number. NR-2B, NR-3A, NR-5C, and NR-10 are all different models of air conditioners. The NR-5C and NR-10 are briefly described in the following paragraphs.

NR-5C Air Conditioner

The NR-5C air conditioner (fig. 3-14) is a mobile, trailer-mounted, electric-powered by a 30-horsepower, 440-volt, 3-phase, 60-cycle electric motor which is an integral part of the compressor.

The unit is mounted on four wheels. The two rear wheels are non-steerable, shock-absorbing on heavy duty cushion tread tires. Two swivel shock-absorbing wheels are provided on the center front of the unit. The rear wheels incorporate parking brakes that are applied or released by a single manual control lever located at the front of the unit. Access doors and panels are provided for full accessibility. Four lifting rings are mounted on the upper corners of the unit.

The NR-5C air conditioner theory of operation will be covered in chapter 13 of this manual.

NR-10 Air Conditioner

The NR-10 air conditioner (Fig. 3-15) is also a mobile, trailer-mounted, self-contained air-conditioning unit. A six-cylinder, turbocharged

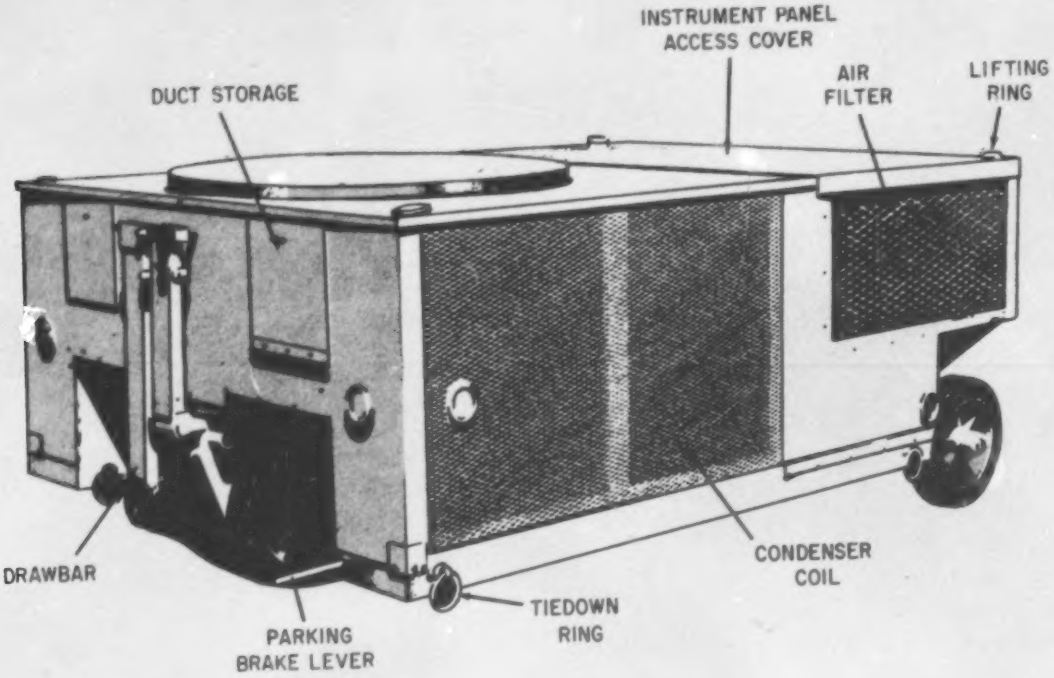

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Figure 3-14.—NR-5C air conditioning unit, 3/4 left front view.

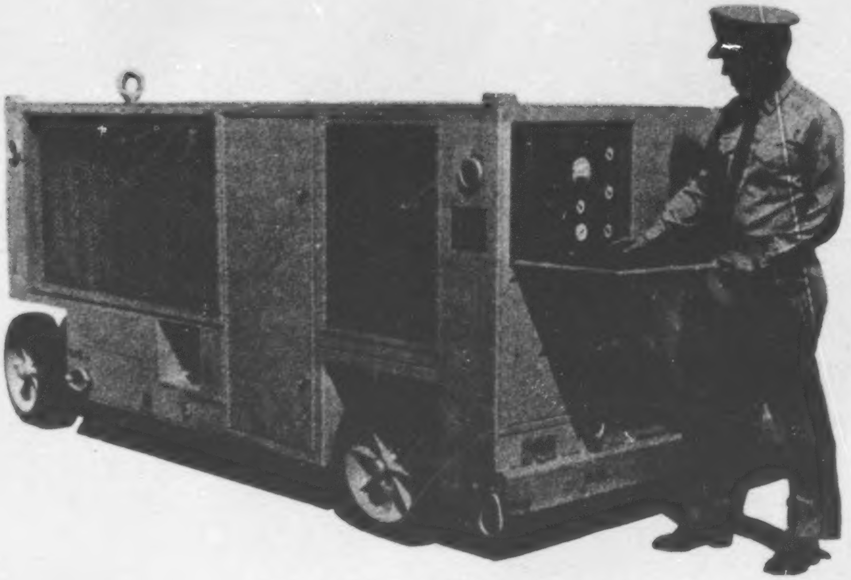
82-horsepower diesel engine supplies all the power for operation of the air conditioner. Incorporated in the engine are a manual throttle, water pump and thermostat, oil filter, fuel injection pump, fuel transfer pump, fuel filters, variable speed governor, overspeed control, thermal protection and low oil pressure safety switches, generator, and starting circuits.

The engine is liquid-cooled by means of a radiator. Air flow through the radiator is provided by the condenser fan. The axle assembly consists of the towbar and four independent suspension wheels. The towbar assembly is designed so that when the front wheels attain their maximum angular position a cam on the towbar assembly is released allowing the towbar to continue following the motion of the towing vehicle. All four wheels are provided with braking.

GAS TURBINE POWER SERVICING EQUIPMENT

Gas turbine power equipments are driven by gas turbines. Although they all employ similar gas turbine engines, there are several different types and configurations of gas turbine power equipments. Basically, these units provide air for jet starting and in some cases will provide electrical power for servicing or starting aircraft. These units may also be used to supply air for safe removal of snow or ice from aircraft and for heating and preheating.

Gas turbine power equipments are largely self-contained and require only an outside source of fuel and oil to maintain a constant output. The units may be enclosed in a skid-mounted enclosure, housed in an aerodynamic pod, or mounted on the rear of a tow tractor, such as the MD-3 described



225.219

Figure 3-15.—NR-10 air conditioner.

previously in this chapter. When housed in an aerodynamic pod, these units are designed to be transported on the bomb shackles under the wings of jet aircraft. The pod is mounted on detachable wheels or on a bomb trailer when in use. Concerning gas turbine power equipment, the inspection, maintenance, and repair of turbine, are the major responsibilities of the ASM.

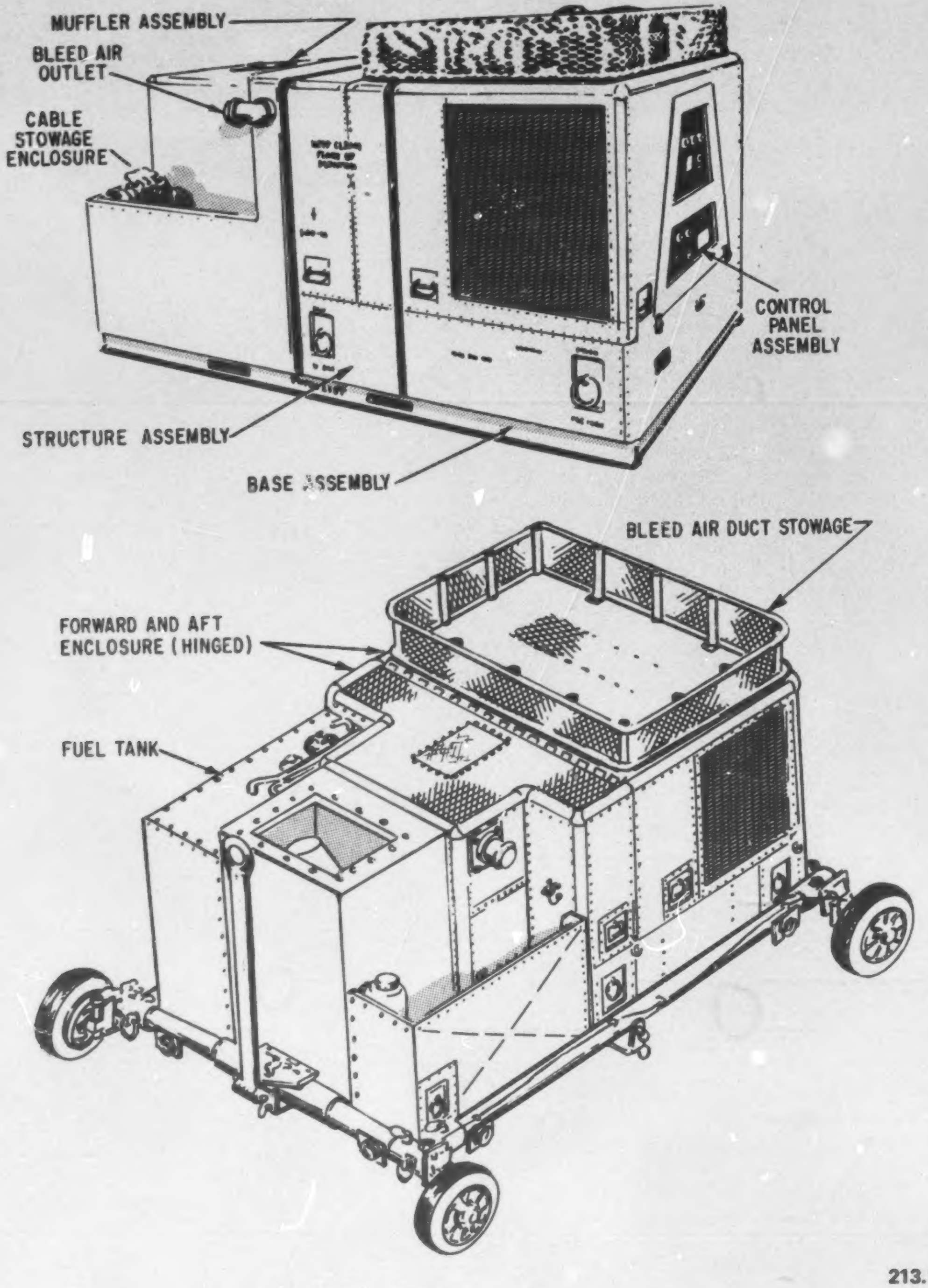
GTC-85, GTCP-100, NCPP-105, and RCPP-105 are all different models of gas turbine compressors. The MD-3, described previously, is equipped with the GTCP-100. The NCPP-105 is described briefly in the following paragraphs.

The NCPP-105 (fig. 3-16) is a complete, self-contained unit consisting of a flyaway assembly enclosed in a skid-mounted, weather-resistant enclosure. The top view of figure 3-16 shows the NCPP-105 as a skid-mounted unit. This unit can be installed on a trailer, as shown in the lower view of figure 3-16. This permits ease of movement from aircraft to aircraft and from place to place.

The NCPP-105 supplies compressed air, at two pressure ratios (5:1 and 3.6:1), for aircraft engine starting, and ac and dc electrical power for operation of aircraft ac and dc electrical components. It is equipped with a remote cable assembly, an ac output cable, a dc output cable, and a bleed air duct assembly.

The unit enclosure consists of a forward and aft closure (hinged together), a cable stowage enclosure, muffler assembly, fuel tank structural assembly, and a base assembly.

The flyaway assembly is normally operated while in the NCPP-105 enclosure, with the dc power supply mounted in the forward enclosure. However, when it is required to transport the flyaway assembly by aircraft to a temporary


MUFFLER ASSEMBLY
BLEED AIR OUTLET
CABLE STOWAGE ENCLOSURE
CONTROL PANEL ASSEMBLY
STRUCTURE ASSEMBLY
BASE ASSEMBLY
BLEED AIR DUCT STOWAGE
FORWARD AND AFT ENCLOSURE (HINGED)
FUEL TANK

213.17

Figure 3-16.—Model NCPP-105 compressor power unit.

location, the dc power supply is removed and relocated on the flyaway assembly structure. The fuel line and ac and dc electrical output cables are disconnected, the forward and aft enclosures are lifted off the structure assembly, and the flyaway assembly is then removed from the base assembly. The flyaway assembly, with its remote cable, ac and dc electrical output cables, and bleed air duct assembly, upon arrival at its temporary location, can be operated by attaching it to a fuel supply.

The control panel is part of the flyaway and is located on one end of the NCPP-105 unit, as shown in figure 3-16. The control panel contains the complete operating instructions for the operation of the unit.

NOTE: The NCPP-105 flyaway assembly cannot be hung as an external store and must be transported inside a transport or cargo-type aircraft.

WEAPONS LOADER

The AERO 47A Weapons Loader (fig. 3-17) is designed primarily for the U.S. Navy to load externally carried munitions, weapons, jato bottles, ammunition cans, rockets, pylons, and fuel tanks onto tactical aircraft. It is used to lift, transport, and attach these items of varying size, weighing up to 4,500 pounds, to the wing and centerline pylons of the aircraft. All lifting and manipulating functions of the weapons loader are hydraulically powered. The vehicle is

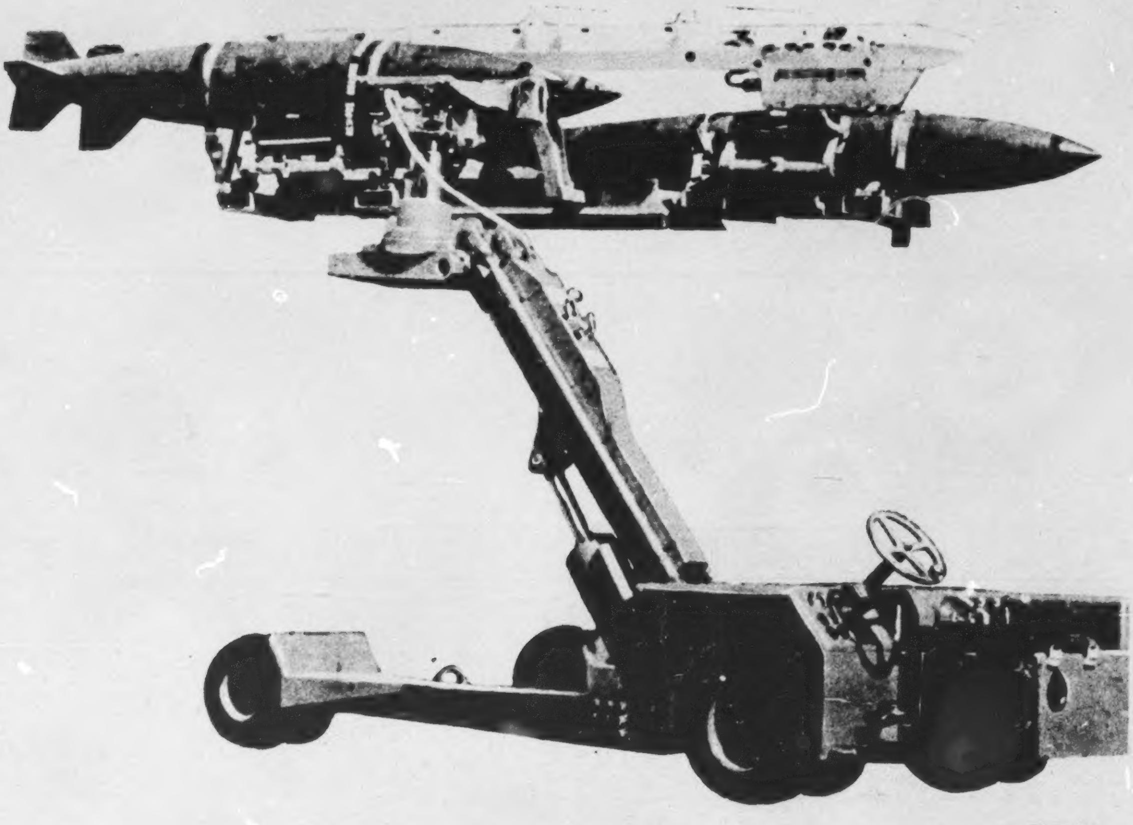


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Figure 3-17.—Aero 47A weapons loader.

powered with a 27.5 horsepower, multifuel burning engine which provides power for the movement of the vehicle as well as the hydraulic system.

The Aero 47A is controlled in a manner similar to conventional forklift trucks. It is equipped with hydraulic powered steering which provides a turning radius of 15 feet. All hydraulic motions, including the lifting mechanism, incorporate safety features which prevent movement of the load in the event of mechanical or hydraulic failure.

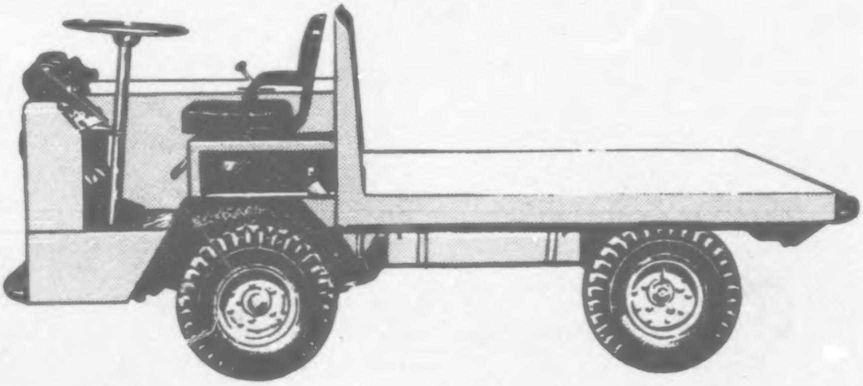
The application of this loader in aircraft loading operations permits the loading of all weapons with a two-man crew. Since the loader permits transportation and handling of prepackaged multiple suspension racks, operations such as individual weapon attachment, sway bracing, fuzing, attaching arming wires, and preliminary rack checkout can be performed as a prestaging operation. Loading time at the aircraft is reduced to an absolute minimum.

The Aero 47A has conventional automotive power steering. The drive train consists of a single disc, dry automotive clutch, a standard 3-speed transmission, a 2-speed transfer case, and a limited slip differential to ensure positive traction. Brakes consist of a mechanical parking brake on the rear wheels and hydraulic service brakes on the rear wheels and two inside front wheels.

P-36 AIRFIELD MAINTENANCE TRUCK

The P-36 airfield maintenance truck (fig. 3-18) is a platform truck capable of hauling loads up to 3,600 lb. A 34-horsepower, four-cylinder, air-cooled engine provides the power. The open operator's compartment is located at the front of the truck beside the engine. The transmission and steering are manually operated. The ignition system is the coil and distributor type. The maximum governed speed of the engine is 2,175 rpm producing a top speed of 15 mph. Hydraulically operated brake shoes inside each wheel brake drum provide a means of braking the truck. The standard shift transmission unit provides two forward and one reverse speeds. The six volt lead acid storage battery, generator, and voltage regulator system is the source of power for the starting, ignition, and lighting systems.

This truck is used around airfields for general hauling. It can be used for off-paved surface hauling at low speeds but has only a five-inch clearance. It is provided with a coupler on the rear of the frame to facilitate towing trailers or other vehicles.



225.218

Figure 3-18.—P-36 airfield maintenance truck.

MB-5 AIRCRAFT FIREFIGHTING AND RESCUE TRUCK

Most aircraft firefighting and rescue equipment used on shore stations is maintained by the Public Works Department. On board aircraft carriers, personnel of the AS rating are concerned with the maintenance of this type of equipment. An example of such equipment is the MB-5 Aircraft Firefighting and Rescue Truck.

The MB-5 firetruck the ASM will encounter (fig. 3-19) is manufactured by the Oshkosh Truck Corp. and is used on board aircraft carriers. The main engine is mounted on the rear of the chassis with the fan and radiator to the rear. This engine is a six-cylinder diesel engine displacing 638 cubic inches and rated at 273 horsepower at 2,200 rpm. An exhaust-driven turbocharger compresses the inlet air before it enters the cylinders. When first started, a speed limiting device limits the engine speed until lubricating oil pressure builds up to a safe operating range. The full pressure lubrication system also bypasses the oil cooler and filter when the engine is first started until the temperature of the oil increases to a high enough temperature to flow unrestricted through the oil passages. Oil sprayed on the underside of the pistons assists in cooling the pistons, in addition to providing lubrication. All moving parts of the engine are either pressure-lubricated by a gear type pump or splash lubricated.

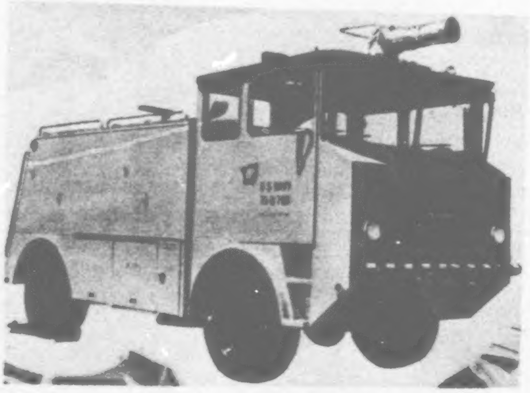


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Figure 3-19.—MB-5 aircraft firefighting and rescue truck.

The engine is of the overhead valve design utilizing mechanical lifters and push rods. Passages in the block and cylinder head circulate a coolant to cool the valves. Thermostatically controlled radiator shutters and a regulator valve in the water jacket restrict the flow of water and cooling air through the radiator to decrease the warmup time of the engine and maintain proper engine operating temperature. The cooling system is pressurized for safe operation at higher than normal temperatures. The coolant is circulated by a centrifugal water pump through the engine oil cooler and the water-cooled air compressor as well as the normal passages. The air compressor, driven by the engine, provides air pressure for the operation of the hydraulic brake system power assist unit, radiator shutter cylinder, windshield wipers, and other units.

The transmission is semiautomatic and provides four speeds forward, neutral, and one reverse speed. The transmission gear selector is located to the right of the driver's seat. Under normal conditions, the vehicle can be operated in 4th gear. In this position the transmission will automatically upshift and downshift with the increase and decrease of engine speed. For off-road or heavy pulling operations, a lower gear range should be selected. With the selector in one of the lower gears, the tachometer should be observed for indicated engine speed. When the engine speed reaches 2,200 rpm, the transmission should be shifted to the next higher gear range. A smooth shift can be obtained if the accelerator is released momentarily while shifting. The lower ranges are also used to aid in braking the vehicle when descending steep grades. However, engine speed should not be allowed to exceed 2,500 rpm. The brakes should be applied as necessary to maintain engine speed below the 2,500 rpm level.

The transmission transmits power to both the front and rear axles through separate drive shafts. A parking brake of the internal expanding type is provided on the output shaft to the front axle.

The MB-5 is equipped with power-assisted steering. The service brakes are of the hydraulic type, and the system incorporates an air-over-hydraulic power assist unit. The volume of compressed air necessary for the operation of the brakes, windshield wiper, and various other control units is supplied from two reservoirs mounted on the chassis. A constant pressure is maintained in these reservoirs by an air compressor which is mounted to and driven by the engine. A recharging valve is provided on one of the reservoirs to facilitate air system charging from an external supply.

An auxiliary power generator set is located on the work deck area just forward of the main engine. The generator set consists of a one-cylinder air-cooled diesel engine coupled to a generator of 1,000-watt capacity. The generator will supply 115-volt, single-phase, 60-hertz current for the operation of hand power tools and accessories and will also supply direct current for battery charging. The generator set may be started from the operator's cab by means of an electrical starting motor. A duplicate set of starting switches is provided for starting at the unit. A means of manual starting is also provided.

Maintenance of the MB-5 requires the coordinated efforts of the using and supporting activities. On board aircraft carriers, the using activity is the V-1 Division of the Air Department, and the supporting activity is the Aircraft Intermediate Maintenance Department (AIMD). Within the V-1 Division, personnel of the ABH rating operate the vehicle. In addition to servicing and performing preoperational inspections, personnel of the V-1 Division are responsible for complete maintenance of the actual firefighting equipment and components. AS personnel of the AIMD are responsible for calendar inspection and major repair of the vehicle itself.

HYDRAULIC TEST STANDS

Portable hydraulic test stands provide a means of simulating the aircraft engine-driven hydraulic pump. By connecting a test stand to the aircraft's hydraulic system, the various actuating systems may be operated without turning up the aircraft engine. The test stand is connected to the aircraft's hydraulic system at ground test couplings (quick disconnects) provided on the aircraft. In addition to ground checking aircraft hydraulic systems, most test stands can be used for flushing and filling the hydraulic system with micronically filtered hydraulic fluid MIL-H-83282 or MIL-H-5606.

Portable hydraulic test stands, such as the AHT-63 and AHT-64 (see fig. 3-20), are frequently referred to as hydraulic jennys. The AHT-63 and the AHT-64 hydraulic test stand is manufactured by the SUN ELECTRIC CORP. or the LIQUIDONICS CORP.

The AHT-63 is powered by a 50-hp, 3520-rpm, 220/440-v, 60-Hz, 3-phase, 128/64-ampere motor. It drives an axial piston-type pump which is variable-volume pressure-compensated. (24 gpm at 3000 psi to 13 gpm at 5000 psi). The AHT-64 (see fig. 3-20) operates the same as the AHT-63 except it is powered by a 3-cylinder, 2-cycle diesel engine.

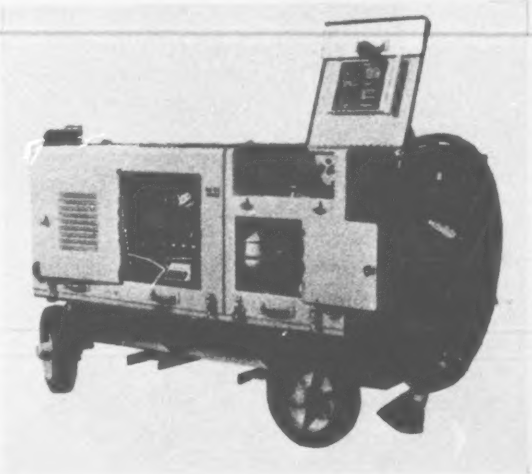

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Figure 3-20.—Portable hydraulic test stand, Model AHT-64.

STEAM CLEANERS

A steam cleaner (fig. 3-21) serves as a compact, mobile, easily operated means of cleaning and degreasing vehicles, vehicle parts, aircraft engines, machinery, and all equipment not subject to damage by the application of moisture. Often those parts of equipment that will be damaged by moisture can be covered with moisture-proof material and the equipment still be steam cleaned. The steam cleaner can also be used for sterilization, disinfecting, and paint removal.

A one-cylinder three-horsepower, air-cooled gasoline engine powers the cleaner. It has a magneto ignition system and is similar to the engines mounted on many powered lawn mowers. It furnishes power via a V-belt arrangement to drive the two piston-type fuel and water pumps, the burner magneto, and the blower fan. A governor holds the engine speed steady during operation. A centrifugal clutch couples the engine to the V-belt drive pulley of the system. The clutch disengages the engine from the cleaner system when the engine is at idle speed, and automatically engages the engine with the system when the engine is advanced to operating speed.

The burner fuel pump pumps kerosene to the burner where it is vaporized. The burner magneto furnishes the spark to ignite and keep the kerosene burning. Cleaning compound in solution with water is pumped into the heater coil where it is brought to a high temperature. The vapor spray that is forced into the delivery hose at high pressure is a mixture of steam, water, and cleaning compound. The cleaning gun assembly, used to direct the vapor on objects to be cleaned, has an insulated handle.

HONING MACHINE

The portable dry honing machine (fig. 3-22) is a compact, self-contained, lightweight (160 lb), portable unit used for cleaning small work pieces and for the safe and convenient removal of corrosion through the dry honing process. Although it is used principally for aircraft and aircraft component corrosion removal it is equally effective on equipment within the maintenance field of work of the ASM. The machine must have an outside source of air to

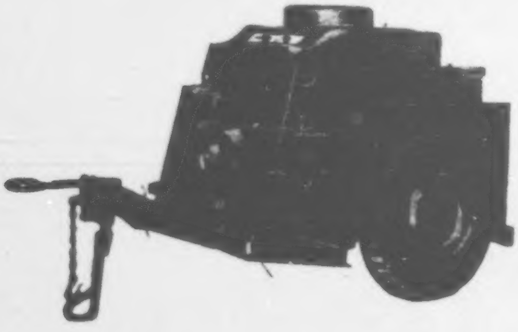

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Figure 3-21.—Steam cleaner.

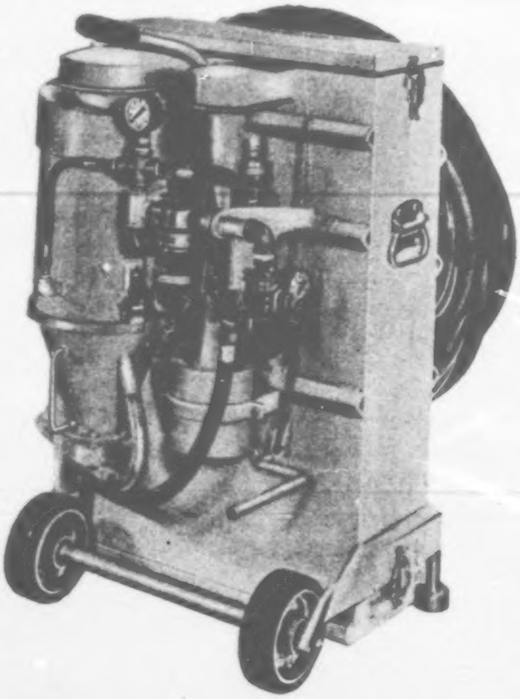

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Figure 3-22.—Dry honing machine.

operate. The abrasive is either glass beads or aluminum oxide particles. The glass beads are used on metals that will corrosively react with aluminum should the aluminum oxide be used.

The blast gun assembly consists of a hand-held gun (fig. 3-23), blast control valve, nozzle assembly, and the connections for air, abrasive supply, and abrasive return hoses. The abrasive is fed into the flow of air which is then directed against the work piece. Abrasive and debris are then returned to the filter bags by an air ejector pump or an electrical pump that has been installed on some units.

To use, hold the blast gun firmly against the surface to be dry honed and press the blast control valve at the gun. Move the gun smoothly over the surface in a uniform manner. To prepare the work piece, remove all oil, water, and other debris before starting the dry honing process. To prevent lose of abrasives, the blast control valve must be released before the gun is raised from the surface.

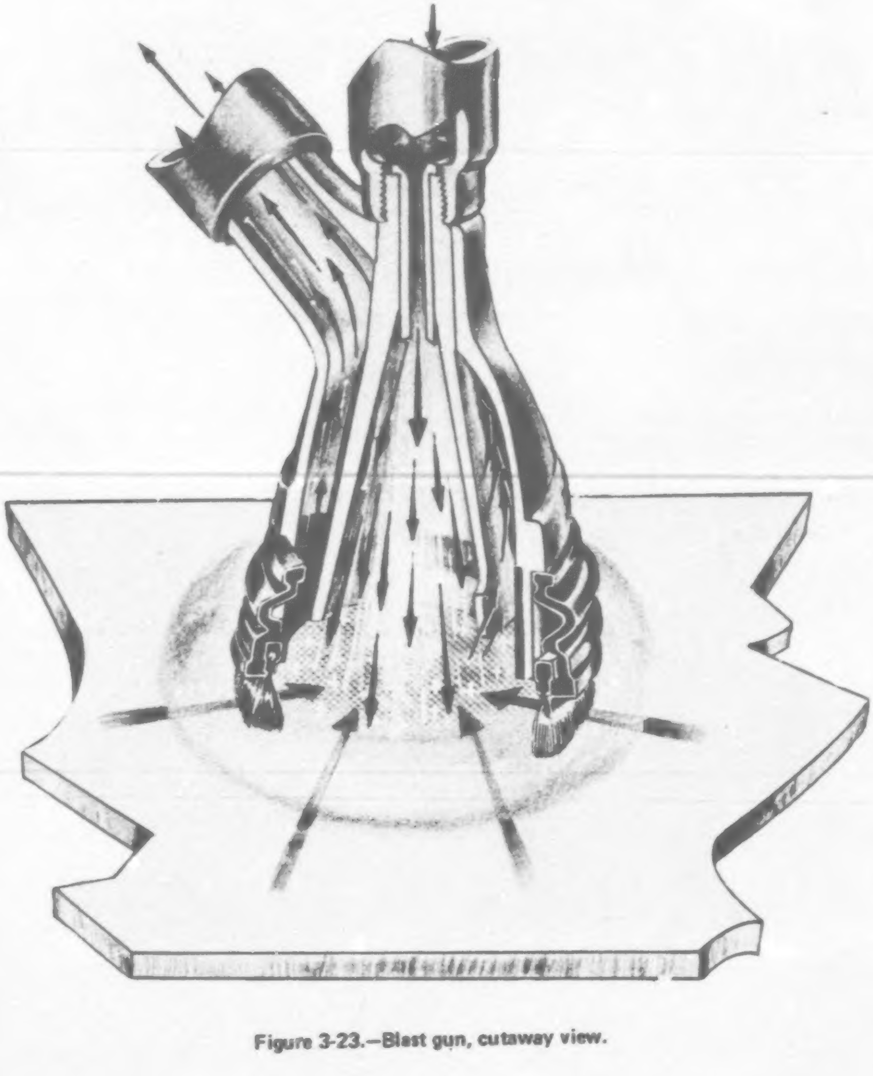

Figure 3-23.—Blast gun, cutaway view.

PORTABLE AIR COMPRESSORS

The P5R air compressor (fig. 3-24) is intended for use in charging low and high pressure pneumatic systems on aircraft. It can meet requirements for low pressure air servicing from 0 to 1,000 psig and high pressures from 1,000 to 5,000 psig. The engine powering the unit is a four-stroke cycle, gasoline burning, internal combustion, air-cooled, four-cylinder, V-type with in-the-block valves. The engine is equipped with a float-type carburetor, single diaphragm nonpositive fuel pump, shielded magneto ignition, electric starter, and centrifugal flyball type of governor for controlling engine speed.

The chassis is of welded steel frame construction. The running gear assembly consists of front wheels and suspension that are controlled by automotive type steering linkage hooked to the towbar. The rear wheels are equipped with expanding shoe parking brakes activated by a hand lever on the towbar end of the frame.

A portable air compressor used principally to inflate tires is similar tc the one described in chapter 2 of this manual. These air compressors are usually powered by an air cooled gasoline engine similar to the one that has been described powering the steam cleaner.

TRAILERS, DOLLIES, AND CARTS

The trailers usually found as part of aviation support equipment are special-use, unpowered, four-wheeled vehicles. They have a towing tongue, and the front wheels are turned in a manner similar to an automobile or are free swiveled. The wheels have either solid or pneumatic tires. Two or more of the wheels are usually equipped with a brake system to permit the trailer to be parked in a desired position.

Trailers are used to move ordnance, oxygen, nitrogen, and LOX. Equipments such as air compressors, aircraft starters, air conditioners, engine preheaters, gas turbine compressors, and preoilers are permanently mounted on trailers. The trailer permits the mobility needed for this type of equipment without the prohibitive cost of an engine and accessories that would not be needed most of the time. Aircraft engine service

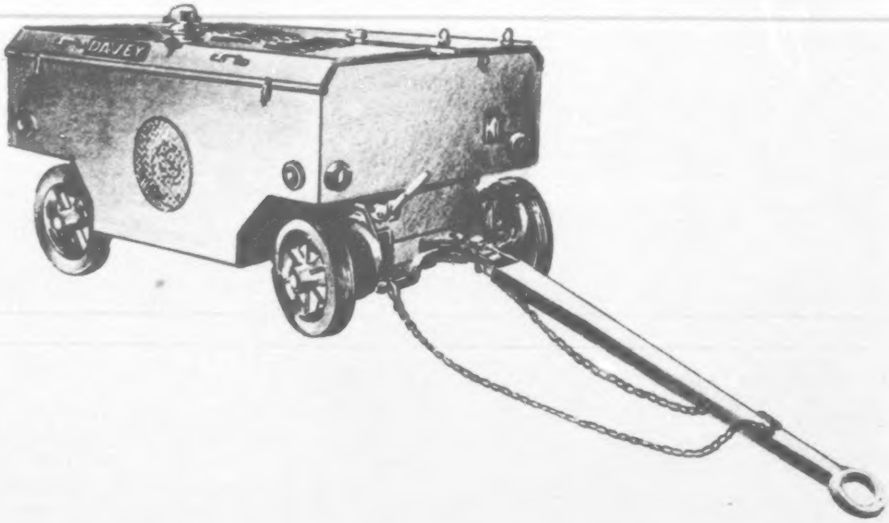

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Figure 3-24.–P5R portable air compressor.

trailers are used to move and support both jet and reciprocating aircraft engines when the engines are removed from the aircraft. These trailers are usually manufactured with the equipment that is mounted on them.

UNPOWERED DOLLIES

Unpowered truck dollies (fig. 3-25) are commonly referred to as crash dollies. They are provided on all carriers for moving heavy aircraft components and to serve as aids in moving crashed aircraft. This is a heavy-duty, low-bed dolly of welded steel construction with a hard fiber top surface and four swiveled, shock absorbing, caster-type wheels with non-sparking tread. Bar rails on all four sides of the dolly provide handholds and places for tiedowns. These dollies can be modified in many different ways to serve specific purposes. One such modification has a heavy steel socket welded to the top of the dolly to insert a landing gear strut when the wheel is broken off. Any modification of the dolly must be sufficiently strong to safely handle the load that will be imposed on it. The aircraft spotting dolly is covered separately in this chapter because it is self-propelled.

CARTS

Carts are two-wheeled vehicles, often having a caster-type small wheel on a stand projecting from the tongue to keep the cart horizontal when not hitched to the towing vehicle. They are used to haul the same material or equipment as trailers, but they have smaller bulk and weight capacity.

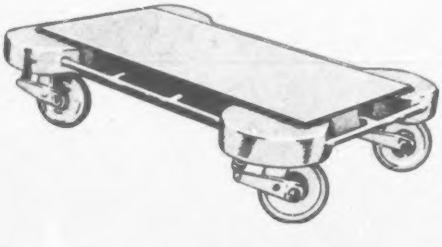

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Figure 3-25.—Aircraft crash dolly.

The ASM's responsibility in the servicing of trailers, dollies, and carts involves only the lubrication of the equipment.

AIRCRAFT SPOTTING DOLLY

The movement of aircraft on the ground and aboard aircraft carriers has historically been accomplished by means of a tow bar and manpower or a tow bar and tractor; however, in crowded areas these methods become ineffective. The aircraft spotting dolly (fig. 3-26) can, while providing maximum maneuverability, tow, turn, and spot several types of aircraft as effectively in congested areas as in the open.

The SD-1D is equipped with a 3-cylinder diesel engine and weighs 7,500 pounds. The unit is manufactured by Consolidated Diesel Electric Corporation. It has a lifting capacity of 16,000 pounds, and can operate under most aircraft as it is only 29 inches high.

Self-propelled, the spotting dolly moves an aircraft by picking up the nosewheel and moving the aircraft in any direction, with no turning radius required by the spotting dolly. The spotting dolly can approach an aircraft head on, pick up the nosewheel, spin on its own axis, and tow the nosewheel directly out at any angle to the aircraft's original line of direction. It can turn an aircraft through 360 degrees while the center of the landing gear remains stationary.

The nosewheel, when loaded on the lifting arms of the spotting dolly, is on a freely revolving turntable located between the two drive wheels of the spotting dolly. A differential drive system permits one drive wheel of the spotting dolly to be driven forward, the other in reverse. This allows the spotting dolly to spin completely about without moving the nosewheel.

The spotting dolly is a 3-wheeled device, two of the wheels being driven and the third, a free-wheeling caster. Control is accomplished through a single handle on the end of the control arm. Steering is accomplished by pushing

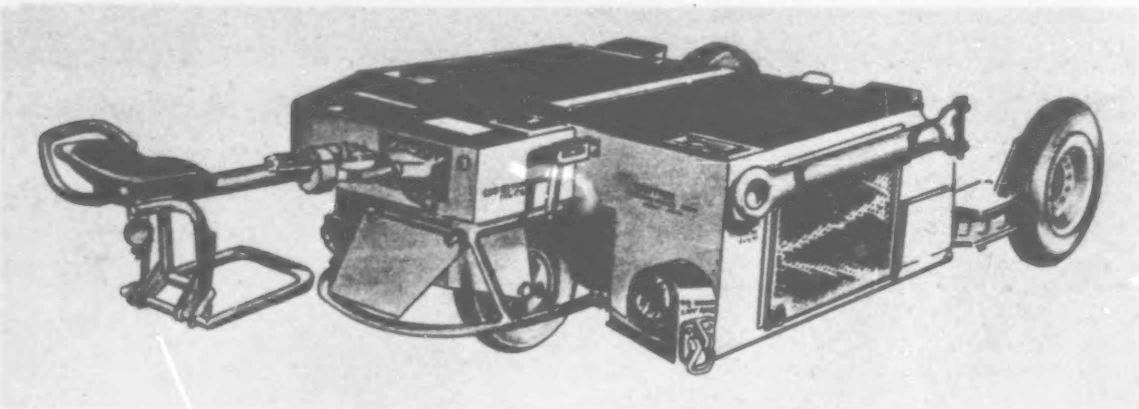

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Figure 3-26.–Aircraft spotting dolly, Model SD-1D.

the handle left or right; speed and direction (forward or reverse) by twisting the handle. The operator may either walk with the unit, or ride on the operator's seat, controlling it with a single hand. Maximum speed for the SD-1D is 2 miles per hour loaded and 5 miles per hour unloaded.

The usual manner of loading an aircraft is to set the brakes on the main landing gear, lower the lifting arms, drive the spotting dolly under the nosewheel, insert two axle pins in the lifting arms, raise the lifting arms, release the aircraft brakes and drive away.

PRESERVATION/DEPRESERVATION TRAILER

Aircraft and aircraft components, as well as support equipment, must be preserved before shipment, storage, or extended repair periods. The preservation must be removed before operating the aircraft or equipment. A preservation/depreservation trailer or cart is used for this purpose. One such unit is illustrated in figure 3-27.

The chassis of this unit is of welded steel construction and so arranged as to be transportable by ship, cargo aircraft, and helicopters. Four-wheel suspension is provided with knuckle-type steering of the front wheels to provide maneuverability. Internal expanding brakes are used to hold the trailer in position when in use. A tow bar is provided with a lunette eye to permit towing by other vehicles. The enclosure is constructed to provide a nonskid working platform for maintenance personnel when servicing aircraft engines. All

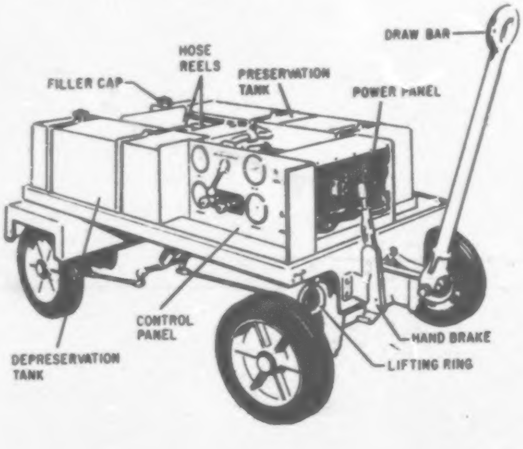

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Figure 3-27.–Preservation/depreservation trailer.

doors and panels are constructed to provide a weather-tight seal and are arranged so that the internal components are readily accessible by personnel for operation, adjustment, or maintenance.

Two oil tanks are provided. An L-shaped depreservation tank with a 20-gallon working capacity is mounted on the right side of the trailer, and a rectangular shaped preservation tank with a 30-gallon working capacity is mounted on the left side. Both tanks are provided with cleanout openings, drains, and filler necks.

This unit is equipped with an electrically driven pump. The pump is capable of delivering either preservation or depreservation fluids at the rate of 3 gallons per minute against a head pressure from 0 to 250 psi. A 3-phase, 3-wire, 220/440-volt, 60-hertz electrical system is provided to operate the pump motor and strip heaters and their controls. The system is so wired that it may be easily connected for operation at either voltage. The system is connected to the external power supply by means of a 3-conductor cable 35 feet long and terminating in a standard 3-prong male plug. The heaters are arranged so that they may be operated at either 220 or 440 volts. They are capable of heating the oil reservoirs from 32° to 250° F within 1 hour.

MECHANICAL SUPPORT EQUIPMENT

The mechanical support equipment with which the ASM is concerned consists of jacks, adjustable aircraft maintenance platforms (workstands), and hoists and slings.

JACKS

Tripod jacks (fig. 3-28) are used when the complete aircraft is to be lifted. They are constructed of steel tubing and bars with a hydraulic cylinder in the middle. Each leg has a pad where the jack rests when being used and a retractable wheel that is used to move the jack. The hand-operated hydraulic pump is located in the bottom of the cylinder. A threaded extension is provided to permit the jack to be used on different aircraft. Inspection of the jack for hydraulic leaks and cracks in the metal should be performed periodically.

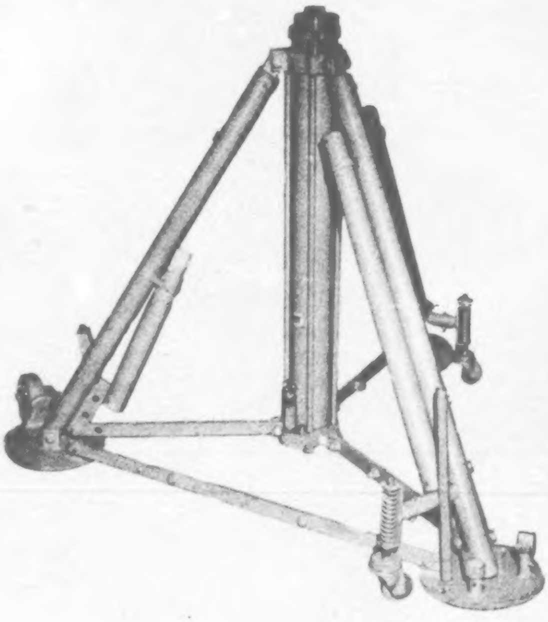

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Figure 3-28.—Tripod jack.

A single base jack (fig. 3-29) is used when only part of the aircraft is to be lifted, such as lifting one wheel of an aircraft.

WORKSTANDS

The B-4A adjustable aircraft maintenance platform (fig. 3-30) is a hydraulically operated platform and ladder assembly mounted on a caster-equipped base, which enables personnel to work in safety at heights varying from a minimum of 3 feet to a maximum of 7 feet. All four wheels have locks to make the platform stationary. Other workstands are often fabricated locally to permit repair of one type of aircraft.

HOISTS AND SLINGS

Chain hoists were covered in chapter 2 of this training course. Other hoists the ASM may be using are the hoists used to lift vehicles for

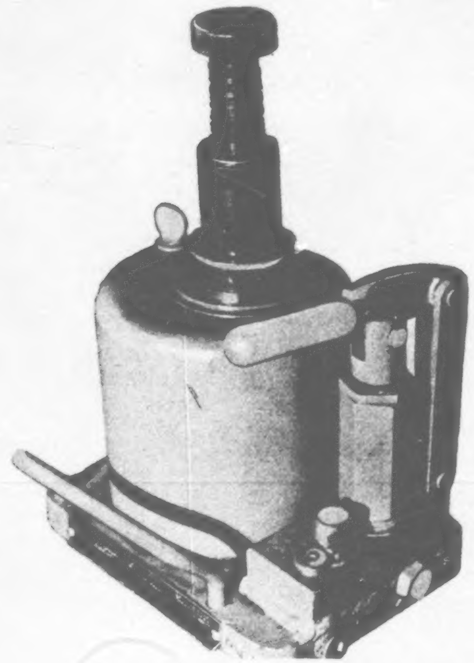

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Figure 3-29.—Single base jack.

lubrication purposes. These hoists use either air or electric power to operate a hydraulic pump that forces the lift cylinder to lift the vehicle. The types found on shore bases are normally the types found in service stations, while the ones found aboard ships are electrically controlled, hydraulically operated, and mobile. Normally these hoists have a three-way valve that controls the hoist. The valve is positioned in the RAISE position for lifting the vehicle, in the OFF position when the lift is up and not in use, and in the lower position for letting the vehicle down.

Some slings are made of cable with a chafing cover of heavy canvas. They are used to lift aircraft that are in other than normal positions because of accidents or crashes. Other hoisting slings are used to hoist aircraft from the dock to the carrier or vice versa. These slings are provided by the aircraft manufacturer. They are attached to the aircraft at several places to ensure the aircraft remains in a horizontal position when being lifted. Still other types of slings are used to lift parts of an aircraft, such as propellers.

Several other types of aviation support equipment may be under the control of the Aviation Support Equipment Technician. These include portable workbenches, special stands for aircraft parts, such as propellers, and cradles into which an engine can be placed after being removed from the aircraft.

GENERAL SAFETY AROUND SUPPORT EQUIPMENT

Safety around aviation support equipment is largely a matter of common sense and not being in too big a hurry. Common sense dictates what measures should be taken to make working around aviation support equipment as safe as possible. Not being in too big a hurry dictates that time must be taken to perform the required safety measures. The full cooperation of all personnel working with and around aviation support equipment is required and constant vigilance must be maintained to eliminate unsafe acts.

General safety rules require that all personnel must strictly observe all safety precautions applicable to their work. Each worker concerned should report, to his supervisor, any unsafe condition, material, or equipment; warn others who appear to be endangered by hazards or by failure to observe safety precautions; and report any injury or evidence of impaired health that occurs to himself or to others. Each worker should wear or use protective clothing or equipment prescribed for the safe performance of the work he is doing. When a hazardous condition occurs, each person should exercise as much caution as is possible under the existing conditions.

Shop safety is covered in chapter 2 of this training course. Some of the safety measures that should be used around aviation support equipment are covered in the following paragraphs.

When stopping self-propelled equipment, set the handbrake or chock the vehicle. This should be done to towed equipment before unhooking.

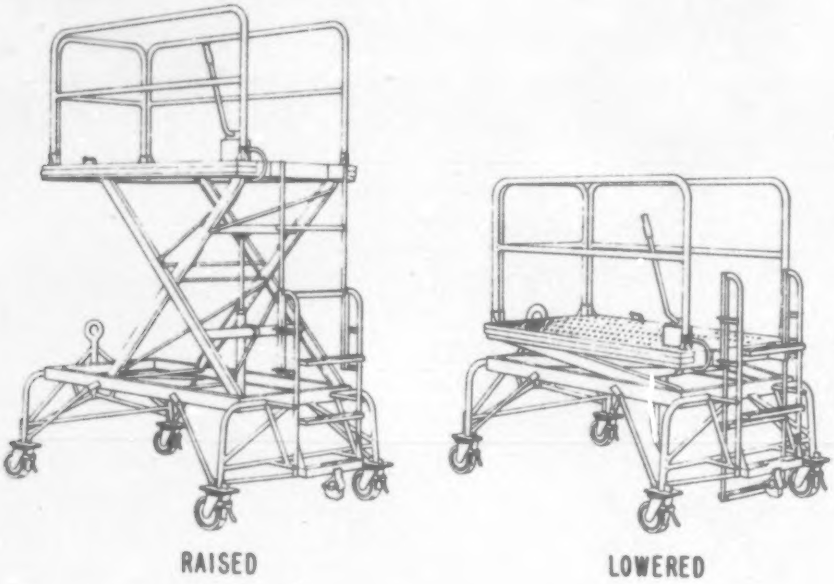

Figure 3-30.—Adjustable aircraft maintenance platform.

When mobile equipment is hand pushed or pulled, this should be done when the vehicle is stopped.

Aboard aircraft carriers, any aviation support equipment that is not in use is tied down to prevent a tight turn or any tilting of the ship from causing the equipment to become a hazard to personnel or equipment. All equipment should be as clean as possible to prevent accumulation of fuel, oil, hydraulic fluid, or grease from becoming a fire hazard or causing slippage by those working with or on the equipment.

Each piece of aviation support equipment should be used only for the purpose for which it was manufactured, except in an emergency, and used only by authorized personnel. The authorization should be in writing and indicate that the holder has been thoroughly checked out in the operation of the equipment and the safety practices associated with it.

CHAPTER 4

PHYSICS

The Aviation Support Equipment Technician M is associated with some very complex machines and equipment. He is expected to understand, operate, service, and maintain these machines and equipment, and to instruct new men so that they can also perform these functions. No matter how complex a machine or item of equipment, its action can be satisfactorily explained as an application of a few basic principles of physics. In order to understand, maintain, and repair the equipment and machinery necessary to the operation of the ships and aircraft of the fleet, an understanding of these basic principles is essential. There can be no question that the technician who possesses this understanding is better equipped to meet the demands placed upon him in his everyday tasks.

Physics is devoted to finding and defining problems, as well as to searching for their solutions. It not only teaches a person to be curious about the physical world, but also provides a means of satisfying that curiosity. The distinction between physics and other sciences cannot be well defined, because the principles of physics also pertain to the other sciences. Physics is a basic branch of science and deals with matter, motion, force, and energy. It deals with the phenomena which arise because matter moves, exerts force, and possesses energy. It is the foundation for the laws governing these phenomena, as expressed in the study of mechanics, hydraulics, magnetism, electricity, heat, light, sound, and nuclear physics. It is closely associated with chemistry and depends heavily upon mathematics for many of its theories and explanations.

BASIC CONCEPTS

In any study of physics, it soon becomes obvious that specific words and terms have specific meanings which must be mastered from the very start. Without an understanding of the exact meaning of the term, there can be no real understanding of the principles involved in the use of that term. Once the term is correctly understood, however, many principles may be discussed briefly to illustrate or to emphasize the particular aspects of interest. The first part of this chapter is devoted to definitions of some physical terms and a brief general discussion of certain particular principles of vital interest to all technical personnel.

MEASUREMENT

In all branches of science, measurement is a a very important consideration. In order to evaluate results, it is often essential to know how much, how far, how many, how often, or in what direction. As scientific investigations become more complex, measurements must become more accurate, and new methods must be developed to measure new things. Measurement can be made by using two different types of units, the English or the metric. The English units of measure are feet, pounds, gallons, and seconds. The metric units of measure are meters, kilograms, liters, and seconds. Most scientific measurement is made by using the metric units.

Measurements may be classed in three broad categories—magnitude, direction, and time. These categories are broken down into several types, each with its own standard units.

Measurements of direction and time have become fairly well standardized and have comparatively few subdivisions. Magnitude, on the other hand, is an extremely complex category with many classes and subdivisions involved.

To illustrate the complexity of the magnitude category, consider only a few common examples of measurement dealing with magnitude–weight, distance, temperature, voltage, size, loudness, brightness, etc.; then consider measurements based on combinations of magnitude–density (weight per unit volume), pressure (force per unit area), thermal expansion (increase in size per degree change in temperature), etc. In addition, measurements combine categories: The flow of liquids is measured in volume per unit of time, speed is measured in distance per unit of time, rotation is measured in revolutions per minute, frequency is expressed in hertz, and so on indefinitely. (The term "hertz" has the same meaning and is replacing the term "cycles per second.")

The importance of measurement and the necessity of selecting the proper measurement cannot be overemphasized. Several systems of measurement further complicate matters. For example, distance may be measured in feet or in meters; weight in pounds or in kilograms; capacity in quarts or in liters; temperature in degrees Fahrenheit, celsius, or Kelvin; density in pounds per cubic foot or in grams per cubic centimeter; angles in degrees or in radians; etc.

In this manual, as in many other texts, specific measurements will be described when and as necessary for clarity.

COMPOSITION OF MATTER

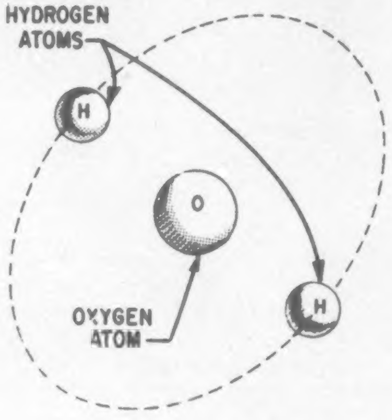

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Figure 4-1.—Molecule of water.

The molecule is the smallest particle to which liquids, solids, or gases can be reduced and still be called by the same name. For example, a molecule of water (H_2O) is composed of one atom of oxygen and two atoms of hydrogen (fig. 4-1). If the molecule of water were divided into oxygen and hydrogen, the water would no longer exist as such. When whole molecules are combined or separated from one another, the change is generally referred to as a physical change. In a chemical change, the molecules of the substance are altered so that new molecules result.

The atom is the smallest particle that makes up the type of material called an element. The element retains its characteristics when divided into atoms. The core of the atom is called the nucleus. It is compared with the sun in the solar system around which the planets revolve. The nucleus contains protons which are positively charged and neutrons which are electrically neutral.

Most of the weight of the atom is in the protons and neutrons of the nucleus. Whirling around the nucleus are one or more smaller particles of negative electrical charge. These are the electrons. Normally there is one proton for each electron in the entire atom so that the net positive charge of the nucleus is balanced by the net negative charge of the electrons whirling around the nucleus. Thus the atom is electrically neutral.

The electrons do not fall into the nucleus even though they are attracted strongly to it. Their motion prevents it, as the planets are prevented from falling into the sun by the centrifugal force of their revolution.

ELEMENT

The word element is used to denote any one of over 100 substances which comprise the basic substance of all matter. Two or more elements may combine chemically to form a compound; any combination which does not result in a chemical reaction between the different elements is called a mixture. The atom represents the smallest particle of an element. An atom of any one element differs from an atom of any other element in the number of protons in the nucleus; all atoms of a given element contain the same number of protons. Thus, it may be seen that the number of protons in the nucleus determines the type of matter.

The various elements are frequently tabulated according to the number of protons. The number of protons in the nucleus of the atom is referred to as the atomic number of the element.

COMPOUNDS AND MIXTURES

Under certain conditions, two or more elements can be brought together in such a way that they unite chemically to form a COMPOUND. The resulting substance may differ widely from any of its component elements; for example, ordinary drinking water is formed by the chemical union of two gases–hydrogen and oxygen. When a compound is produced, two or more atoms of the combining element join chemically to form the MOLECULE that is typical of the new compound. The molecule is the smallest unit that exhibits the distinguishing characteristics of a compound.

Elements or compounds may be physically combined without necessarily undergoing any chemical change. Grains of finely powdered iron and sulfur stirred and shaken together retain their own identity as iron or sulfur. Salt dissolved in water is not a compound; it is merely salt dissolved in water. Each chemical substance retains its chemical identity, even though it may undergo a physical change. This is the typical characteristic of a MIXTURE.

STATES OF MATTER

In their natural condition, forms of matter are classified and grouped in many different ways. One such classification is in accordance to their natural state–solid, liquid, or gas. This classification is important because of the common characteristics possessed by substances in one group which distinguish them from substances in the other groups. However, the usefulness of the classification is limited by the fact that most substances can be made to assume any of the three forms.

In all matter, the molecules are assumed to be in constant motion, and it is the extent of this motion that determines the state of matter. The moving molecular particles in all matter possess kinetic energy of motion. The total of this kinetic energy is considered to be the equivalent of the quantity of heat in a sample of the substance. When heat is added, the energy level is increased, and molecular agitation (motion) is increased. When heat is removed, the energy level decreases, and molecular motion diminishes.

in solids, the motion of the molecules is greatly restricted by the rigidity of the crystalline structure of the material. In liquids, the molecular motion is somewhat less restricted, and the substance as a whole is permitted to "flow." In gases, molecular motion is almost entirely random–the molecules are free to move in any direction and are almost constantly in collision both among themselves and with the surfaces of the container.

This topic and some of its more important implications are discussed in detail under the heading "Heat" in a later section of this chapter.

Solids

The outstanding characteristic of a solid is the tendency to retain its size and shape. Any change in these values requires the exchange of energy. The common properties of a solid are cohesion and adhesion, tensile strength, ductility, malleability, hardness, brittleness, and elasticity. Ductility is a measure of the ease with which the material can be drawn into a wire. Malleability refers to the ability of some materials to assume a new shape when pounded.

Hardness and brittleness are self-explanatory terms. The remaining properties are discussed in more detail in the following paragraphs.

COHESION AND ADHESION.–Cohesion is the molecular attraction between like particles throughout a body, or the force that holds any substance or body together. Adhesion is the molecular attraction existing between surfaces of bodies in contact, or the force which causes unlike materials to stick together.

Cohesion and adhesion are possessed by different materials in widely varying degrees. In general, solid bodies are highly cohesive but only slightly adhesive. Fluids (liquids and gases), on the other hand, are usually quite highly adhesive but only slightly cohesive. Generally a material having one of these properties to a high degree will possess the other property to a relatively low degree.

TENSILE STRENGTH.–The cohesion between the molecules of a solid explains the property called tensile strength. This is a measure of the resistance of a solid to being pulled apart. Steel possesses this property to a high degree, and is thus very useful in structural work. When a break does occur, the pieces of the solid cannot be stuck back together because merely pressing them together does not bring the molecules into close enough contact to restore the molecular force of cohesion. However, melting the edges of the break (welding) allows the molecules on both sides of the break to flow together, thus bringing them once again into the close contact required for cohesion.

ELASTICITY.–If a substance will spring back to its original form after being deformed, it has the property of elasticity. This property is desirable in materials to be used as springs. Steel and bronze are examples of materials which exhibit this property.

Elasticity of compression is exhibited to some degree by all solids, liquids, and gases; the closeness of the molecules in solids and liquids makes them hard to compress, but gases are easily compressed because the molecules are farther apart.

Liquids

The outstanding characteristic of a liquid is its tendency to retain its own volume while assuming the shape of its container: thus a liquid is considered almost completely flexible and highly fluid.

Liquids are practically incompressible; applied pressure is transmitted through them instantaneously, equally, and undiminished to all points on the enclosing surfaces. Hydraulic apparatus can be used to increase or to decrease input forces, thus providing an action similar to that of mechanical advantage in mechanical systems. Because of these properties, hydraulic servomechanisms have advantages as well as disadvantages and limitations when compared with other servosystems.

The fluidity of hydraulic liquids permits the component parts of the system to be placed conveniently at widely separated points when necessary. Hydraulic power units can transmit energy around corners and bends without the use of complicated gears and levers. They operate with a minimum of slack and friction, which are often excessive in mechanical linkages. Uniform action is obtained without vibration, and the operation of the system remains unaffected by variations in load. The accumulator (which provides the necessary pressurization of the system to furnish practically instantaneous response) can be pressurized during periods of nonaction, thus eliminating the "buildup time" characteristic of electric servos.

However, the hydraulic hoses which transmit fluid from unit to unit are bulky and heavy compared to electric wiring. Many of the hydraulic fluids in common usage are messy and constitute safety hazards. They contribute to the danger of slipping, they cause deterioration of the insulation on electric wiring, they conduct electricity and thus increase the hazards of short circuiting, and they are flammable.

The Rate Training Manual *Fluid Power*, NavEdTra 16193 (Series), contains considerable detail on the basic theory of hydraulic systems and units.

Gases

The most notable characteristics of a gas are its tendency to assume not only the shape but also the volume of its containers, and the definite relationship that exists between the volume, pressure, and temperature of a confined gas.

The ability of a gas to assume the shape and volume of its container is the result of its extremely active molecular particles, which are free to move in any direction. Cohesion between molecules of a gas is extremely small, so the molecules tend to separate and distribute themselves uniformly throughout the volume of the container. In an unpressurized container of liquid, pressure is exerted on the bottom and the sides of the container up to the level of the liquid. In a gas, however, the pressure is also exerted against the top surface, and the pressure is equal at all points on the enclosing surfaces.

The relationship of volume, pressure, and temperature of a confined gas are explained by Boyle's law, Charles' law, and the general law for gases.

Many laboratory experiments based on these laws make use of the ideas of "standard pressure"and "standard temperature." These are not natural standards, but are standard values selected for convenience in laboratory usage. Standard values are generally used at the beginning of an experiment, or when a temperature or a pressure is to be held constant. Standard temperature is 0°C, the temperature at which pure ice melts. Standard pressure is the pressure exerted by a column of mercury 760 millimeters high. In many practical uses, these standards must be changed to other systems of measurement.

All calculations based on the laws of gases make use of "absolute" temperature and pressure. These topics require a somewhat more detailed explanation.

GAS PRESSURE.–Gas pressure may be indicated in either of two ways–absolute pressure or gage pressure. Since the pressure of an absolute vacuum is zero, any pressure measured with respect to this reference is referred to as "absolute pressure." In the present discussion, "absolute pressure" represents the actual pressure exerted by the confined gas.

At sea level the average atmospheric pressure is approximately 14.7 pounds per square inch (psi). This pressure would, in a mercurial barometer, support a column of mercury 760 millimeters in height. Thus, normal atmospheric pressure is the standard pressure mentioned previously.

However, the actual pressure at sea level varies considerably; and the pressure at any given altitude above sea level differs from that at sea level. Therefore, it is necessary to take into consideration the actual atmospheric pressure when converting absolute pressure to gage pressure (or vice versa).

When a pressure is expressed as the difference between its absolute value and that of the local atmospheric pressure, the measurement is designated "gage" pressure, and is usually expressed in "pounds per square inch gage" (psig). Gage pressure may be converted to absolute pressure by adding the local atmospheric pressure to the gage pressure.

ABSOLUTE ZERO.–Absolute zero, one of the fundamental constants of physics, is usually expressed in terms of the Celsius scale. Its most predominant use is in the study of kinetic theory of gases. In accordance with the kinetic theory, if the heat energy of a given gas sample could be progressively reduced, some temperature should be reached at which the motions of the molecules would cease entirely. If accurately determined, this temperature could then be taken as a natural reference, or a true "absolute zero" value.

Experiments with hydrogen (making use of the proven correlation with the volume, temperature, and pressure of gases and by calculations based on this correlation) indicated that if a gas were cooled to -273.16°C (used as -273° for most calculations), all molecular motion would cease and no additional heat could be extracted from the substance. At this point the pressure would shrink to zero.

When temperatures are measured with respect to the absolute zero reference, they are said to be expressed in the absolute, or Kelvin, scale. Thus, absolute zero may be expressed either as 0°K or as -273°C.

BOYLE's LAW.—The English scientist Robert Boyle was among the first to study what he called the "springiness of air." By direct measurement he discovered that when the temperature of an enclosed sample of gas was kept constant and the pressure doubled, the volume was reduced to half the former value; as the applied pressure was decreased, the resulting volume increased. From these observations, he concluded that for a constant temperature the product of the volume and pressure of an enclosed gas remains constant. Boyle's law is normally stated: "The volume of an enclosed dry gas varies inversely with its pressure, provided the temperature remains constant.

In equation form this relationship may be expressed either

$$V_1P_1 = V_2P_2, \text{ or}$$

$$\frac{V_1}{V_2} = \frac{P_2}{P_1}$$

where V_1 and P_1 are the original volume and pressure, and V_2 and P_2 are the revised volume and pressure.

CHARLES' LAW.—The French scientist Jacques Charles provided much of the foundation for the modern kinetic theory of gases. He found that all gases expand and contract in direct proportion to the change in the absolute temperature, provided the pressure is held constant. Expressed in equation form, this part of the law may be expressed

$$V_1T_2 = V_2T_1, \text{ or}$$

$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$

where V_1 and V_2 refer to the original and final volumes, and T_1 and T_2 indicate the corresponding absolute temperatures.

Since any change in the temperature of a gas causes a corresponding change in volume, it is reasonable to expect that if a given sample of a gas were heated while confined within a given volume, the pressure should increase. By actual experiment, it was found that the increase in pressure was approximately 1/273 of the 0°C pressure for each 1°C increase. Because of this fact, it is normal practice to state this relationship in terms of absolute temperature. In equation form, this part of the law becomes

$$P_1T_2 = P_2T_1, \text{ or}$$

$$\frac{P_1}{P_2} = \frac{T_1}{T_2}$$

In words, this equation states that with a constant volume, the absolute pressure of a gas varies directly with the absolute temperature.

GENERAL GAS LAW.—The facts concerning gases discussed in the preceding sections are summed up and illustrated in figure 4-2. Boyle's law is expressed in (A) of the figure, and the effects of temperature changes on pressure and volume (Charles' law) are illustrated in (B) and (C), respectively.

By combining Boyle's and Charles' laws, a single expression can be derived which states all the information contained in both. This expression is called the GENERAL GAS EQUATION, a very useful form of which is given by the following equation. (NOTE: The capital P and T signify absolute pressure and temperature, respectively.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

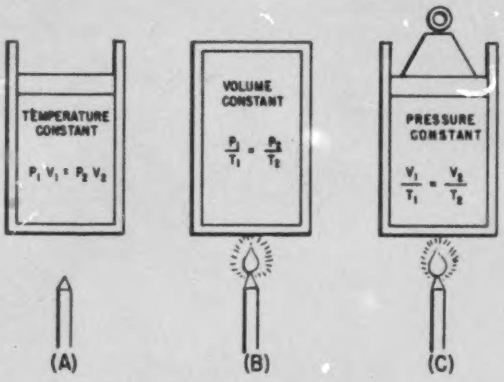

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Figure 4-2.—General gas law.

It can be seen by examination on figure 4-2 that the three equations are special cases of the general equation. Thus, if the temperature remains constant, T_1 equals T_2 and both can be eliminated from the general formula, which then reduces to the form shown in (A). When the volume remains constant, V_1 equals V_2 thereby reducing the general equation to the form given in (B). Similarly, P_1 is equated to P_2 for constant pressure, and the equation then takes the form given in (C).

The general gas law applies with exactness only to "ideal" gases in which the molecules are assumed to be perfectly elastic. However, it describes the behavior of actual gases with sufficient accuracy for most practical purposes.

MECHANICS

Mechanics is that branch of physics which deals primarily with the ideas of force, mass, and motion. Normally considered the fundamental branch of physics, it deals with matter. Many of its principles and ideas may be seen, measured, and tested. Since all other branches of physics are also concerned (to some extent at least) with force, mass, and motion, a thorough understanding of this section will aid in the understanding of later sections of this chapter.

FORCE, MASS, AND MOTION

Each particle in a body is acted upon by gravitational force. However, in every body there is one point at which a single force, equal to the gravitational force and directed upward, would sustain the body in a condition of rest. This point is known as the CENTER OF GRAVITY, and represents the point at which the entire mass of the body appears to be concentrated. The gravitational effect is measured from the center of gravity. In symmetrical objects of uniform mass, this is the geometrical center. In the case of the earth, the center of gravity is near the center of the earth.

When considering the motion of a body, it is usually convenient to describe the path followed by the center of gravity. The natural tendency of a moving body is to move in a manner so that the center of gravity travels in a straight line. Movement of this type is called LINEAR motion.

Some moving bodies, however, do not move in a straight line, but describe an arc or a circular path. Circular motion falls into two general classes—rotation and revolution.

Since objects come in many different shapes and in order to discuss rotary and revolutionary motion, it becomes necessary to consider the location of the center of gravity with respect to the body. (Refer to figure 4-3 for the following discussion.)

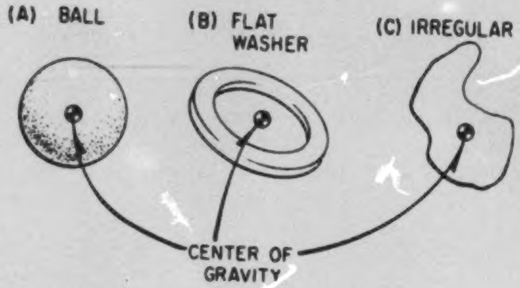

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Figure 4-3.—Center of gravity in various bodies.

In (A), the center of gravity of a ball coincides with the physical center of the ball. However, in the flat washer (B), the center of gravity does not coincide with any part of the object, but is located at the center of the hollow space inside the ring. In irregularly shaped bodies, the center of gravity may be difficult to locate exactly.

If the body is completely free to rotate, the center of rotation coincides with the center of gravity. On the other hand, the body may be restricted in such a manner that rotation is about some point other than the center of gravity. In this event, the center of gravity revolves around the center of rotation. This condition is illustrated in figure 4-4.

In general usage, the gyro rotor (A) is said to ROTATE about its axis, and the ball (B) is said to REVOLVE about a point at the center of its path.

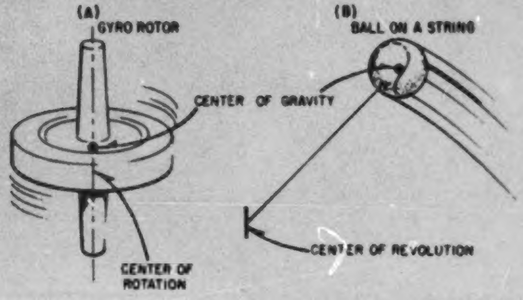

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Figure 4-4.—Center of gravity and center of rotation.

MASSES IN MOTION

Any change in the speed or direction of motion of a body is known as acceleration and requires the application of some force. The acceleration of a body is directly proportional to the force causing that acceleration; acceleration depends also upon the mass of the body. The greater mass of a lead ball makes it harder to move than a wooden ball of the same diameter. The wooden ball moves farther with the same push.

These observations point to a connection between force, mass, and acceleration, and indicate that the acceleration of a body is directly proportional to the force exerted on the body and inversely proportional to the mass of that body. In mathematical form, this relationship may be expressed as

$$a = \frac{F}{m}$$

or, as it is more commonly stated: Force is equal to the product of the mass and acceleration (F = ma).

If the accelerating force is applied to the center of gravity in such a manner as to accelerate the body with no rotation, it is called a TRANSLATIONAL force. A force applied in such a manner as to cause the body to rotate about a point is called a TORQUE force.

Laws of Motion

Among the most important discoveries in theoretical physics are the three fundamental laws of motion attributed to Newton. Although some of these laws have been used in explanations of various topics earlier in this chapter, they are restated and consolidated at this point to clarify and summarize much of the discussion regarding mechanical physics. This restatement and consolidation are also used to introduce additional aspects involving the applications of basic mechanical principles.

1. Every body tends to maintain a state of uniform motion unless a force is applied to change the speed or direction of motion.
2. The acceleration of a body is directly proportional to the magnitude of the applied force and inversely proportional to the mass of the body; acceleration is in the direction of the applied force.
3. For every force applied to a body, the body exerts an equal force in the opposite direction.

Momentum

Every moving body tends to maintain uniform motion. Quantitative measurement of this tendency is proportional to the mass of the body, and also to its velocity. (Momentum = mass x velocity.) This explains why heavy objects in motion at a given speed are harder to stop than lighter objects, and also why it is easier to stop a given body moving at low speed than it is to stop the same body moving at high speed.

WORK, POWER, AND ENERGY

As defined earlier, energy is the capacity for doing work. In mechanical physics, WORK involves the idea of a mass in motion, and is usually regarded as the product of the applied force and the distance through wich the mass is moved (work = force x distance). Thus, if a man raises a weight of 100 pounds to a height of 10 feet, he accomplishes 1,000 foot-pounds of work. The amount of work accomplished is the same regardless of the time involved. However, the RATE of doing the work may vary greatly.

The rate of doing work (called POWER) is defined as the work accomplished per unit of time (power = work/time). In the example cited above, if the work is accomplished in 10 seconds, power is being expended at the rate of 100 foot-pounds per second; if it takes 5 minutes (300 seconds), the rate is approximately 3.3 foot-pounds per second.

In the English system of measurements, the unit of mechanical power is called the HORSEPOWER and is the equivalent of 33,000 foot-pounds per minute; or 550 foot-pounds per second. Since energy is readily convertible from one form to another, the work and power measurements based on the conversion of energy must also be readily convertible. As an example, the electrical unit of power is the watt. Electrical energy may be converted into mechanical energy; therefore, electrical power must be convertible into mechanical power. One horsepower is the mechanical equivalent of 746 watts of electrical power, and is capable of doing the same amount of work in the same time.

The accomplishment of work always involves a change in the type of energy, but does not normally change the total quantity of energy. Thus, energy applied to an object may produce work, changing the composition of the energy possessed by the object. When the work stops, energy is no longer being "expended," so energy must once again be converted in form–but not necessarily into its original form.

Efficiency

Provided there is no change in the quantity of matter, energy is convertible with no gain or loss. However, the energy resulting from a given action may not be in the desired form–it may not even be usable in its resultant form. In all branches of physics, this concept is known as EFFICIENCY.

The energy expended is always greater than the energy recovered. An automobile in motion possesses a quantity of kinetic energy dependent on its mass and velocity. In order to stop the car, this energy must be converted into potential energy. When the car is at rest, its potential energy is considerably less than the kinetic energy it possessed while in motion. The difference, or the "energy lost," is converted into heat by the brakes. The heat serves no useful purpose, so the recovered energy is less than the expended energy–the system is less than 100 percent efficient in converting kinetic to potential energy.

The term efficiency is normally used in connection with work and power considerations to denote the ratio of the input to the output work, power, or energy. It is always expressed as a decimal or as a percent less than one.

Friction

In mechanical physics, the most common cause for the loss of efficiency is FRICTION. Whenever one object is slid or rolled over another, irregularities in the contacting surfaces interlock and cause an opposition to the force being exerted. Even rubbing two smooth pieces of ice together produces friction, although of a much smaller magnitude than in the case of two rough stones. Friction also exists in the contact of air with all exposed parts of an aircraft in flight, as well as in the brakes of the automobile mentioned above.

When a nail is struck with a hammer, the energy of the hammer is transferred to the nail, and the nail is driven into a board. The depth of penetration depends on the momentum of the hammer, the size and shape of the nail, and the hardness of the wood. The larger or duller the nail and the harder the wood, the greater the friction, and therefore the lower the efficiency and less depth of penetration–but the greater the heating of the nail.

Friction is always present in moving machinery and accounts in part for the fact that the useful work accomplished by the machine is never as great as the energy applied. Work accomplished in overcoming friction is usually not recoverable. Friction can be minimized by decreasing the number of contacting points, by making the contacting areas as small and as smooth as possible, by the use of bearings, or by the use of lubricants.

There are two kinds of friction–sliding and rolling, with rolling friction usually of lower magnitude. Therefore, most machines are constructed so that rolling friction is present rather than sliding friction. The ball bearing and the roller bearing are used to convert sliding friction to rolling friction. A third type, the common (or friction) bearing, utilizes lubricants applied to surfaces which have been made as smooth as possible. Many new types of machines utilize self-lubricating bearings to minimize friction and thus increase efficiency.

Mechanical Advantage

The concept of mechanical advantage has proved to be one of the great discoveries of science. It permits an increase in force or distance and represents the basic principle involved in levers, block and tackle systems, screws, hydraulic mechanisms, and other work-saving devices. However, in the true sense, these devices do not save work, they merely enable humans to accomplish tasks which might otherwise be beyond their capability. For example, a human would normally be considered incapable of lifting the rear end of a truck in order to change a tire; but with a jack, a block and tackle, or a lever, the job can be made comparatively easy.

Mechanical advantage is usually considered with respect to work. Work represents the application of a force through a distance in order to move an object through a distance. Thus, it may be seen that there are two forces involved, each with an appropriate distance. This is illustrated by the simple lever in figure 4-5.

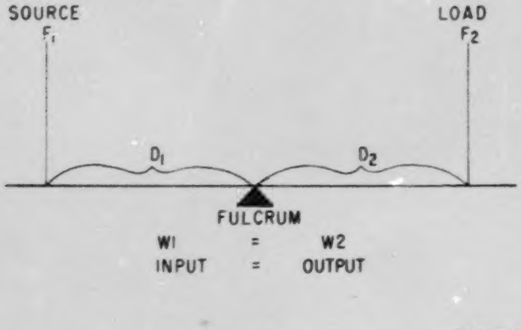

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Figure 4-5.—Mechanical advantage.

Assuming perfect efficiency, the work input (F_1D_1) is equal to the work output (F_2D_2). Assuming equal distances D_1 and D_2, a force of 10 pounds must be applied at the source in order to counteract a weight of 10 pounds at the load. By moving the fulcrum nearer the load, less force is required to balance the same load. This is a mechanical advantage of force. If the force is applied in such a manner as to raise the load 1 foot, the source must be moved through a distance greater than 1 foot. Thus, mechanical advantage of force represents a mechanical disadvantage of distance. By moving the fulcrum nearer the source, these conditions are reversed.

Since the input work equals the output work (assuming no losses), the mechanical advantage may be stated as a ratio of the force or of the distances. In actual situations, friction results in energy loss and decreased efficiency, thereby requiring an even greater input to accomplish the same work.

A more detailed discussion of mechanical advantages and the characteristics of the six basic mechanical devices (the lever, the screw, the inclined plane or wedge, the block and tackle, and wheel and axle, and the gear) is found in the Rate Training Manual, *Basic Machines*, NAVEDTRA 10624 (Series).

REVOLVING BODIES

Revolving bodies represent masses in motion; therefore, they possess all the characteristics (and obey all the laws associated with moving bodies. In addition, since they posses a specific type of motion, they have special properties and factors which must be taken into consideration.

Revolving bodies travel in a constantly changing direction, so they must be constantly subjected to an accelerating force. Momentum tends to produce linear motion, but this is prevented by application of a force which restrains the object. This restraining force prevents the object from continuing in a straight line, and is known as CENTRIPETAL force. According to Newton's third law of motion, the centripetal force must be opposed by an equal force which tends to produce linear motion.

This second force is known as CENTRIFUGAL force. The two forces, their relationships, and their effects are illustrated in figure 4-6 and the following explanatory example.

The various forces involved in revolving bodies may be illustrated by use of a ball and string. A slip knot is tied in the center of a 10-foot length of twine so as to shorten the line to 5 feet; a rubber ball is attached to one end of the string. Holding the other end of the line, whirl the ball slowly in a circle. Note that the ball exerts a force against the hand (through the string); and that in order to restrain the ball in its circular path, the hand must exert a force (through the string) on the ball. As the ball is revolved at higher speed, the forces increase, and the ball continues in a circular path. As the rotational velocity of the ball is gradually increased, note the increasing forces.

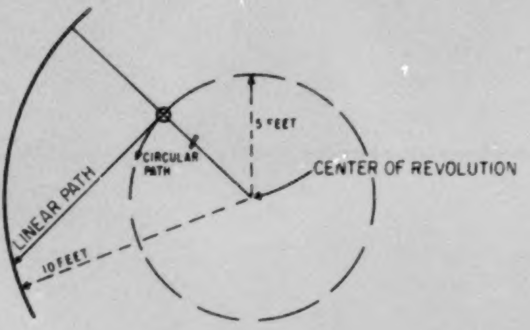

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Figure 4-6.—Forces on revolving bodies.

At some rotational speed, the forces involved become great enough to overcome inertial friction, and the knot slips. At this time, allow the velocity of the rotation to stabilize (stop increasing in rotational velocity, but not slowing down, either), so that the existing conditions may be anaiyzed. When the knot slips, the ball is temporarily unrestrained and is free to assume linear motion in the direction of travel at that instant (tangent to the circle at the instantaneous position). The ball travels in a straight line until the string reaches its full length; during this time, no force is exerted on or by the hand. As soon as all the slack is taken up, there is a sharp jerk—an accelerating force is exerted in order to change the direction of motion from its linear path into a circular rotation. The ball again assumes rotational motion, but with an increase in radius.

The ball does not make as many revolutions in the same time (rotational velocity is decreased), but it does maintain its former linear velocity. (The kinetic energy and the momentum of the ball have not changed.) Since the change in direction is less abrupt with a large radius than with a small one, less accelerating force is required, and the hand will feel less force. If the ball is then accelerated to the same rotational velocity as immediately prior to the slipping of the knot, the linear velocity of the ball becomes much greater than before; the centripetal and centrifugal forces are also greater.

In this example, it has been assumed that the hand is fixed at a point which represents the center of rotation. This assumption, while somewhat erroneous, does not affect the general conclusions. For practical purposes, the two forces are equal at all points along the string at any given time, and the magnitude of each force is equal at all points along the string.

In summarizing the conclusions reached by the above example and explanation, consider the following relationship:

$$\text{Force} = \frac{\text{mass x (velocity)}^2}{\text{radius}} \text{ or } F = \frac{mv^2}{r}$$

where velocity represents the linear velocity of the ball. This emphasizes that the centripetal and the centrifugal forces are equal in magnitude and opposite in direction. Each force is directly proportional to the weight of the body and inversely proportional to the radius of rotation. Each force is also proportional to the square of the velocity.

In revolving or rotating bodies, all particles of the matter which are not on the axis of rotation are subjected to the forces just described. The statement is true whether the motion is through a complete circle or merely around a curve: An aircraft tends to skid when changing course; an automobile tends to take curves on two wheels. The sharper the curve (smaller radius) or the higher the velocity, the greater the tendency to skid.

WAVE MOTION

Wave motion and radiated energy may be compared with the wave motion of water. When a pebble is dropped into a calm pool of water, a series of circular waves travel away from the disturbance. These waves radiate in all directions on the surface of the water until they are absorbed or until they are diverted by coming into contact with an obstruction of some sort. Water waves are a succession of crests and troughs; the distance from one point to the next identical point on the wave is called wavelength. A cork floating on the surface of the water bobs up and down with the waves, but moves very little in the direction of wave travel. Water waves are called transverse waves because the motion of the water particles is up and down, or at right angles (transverse) to the direction in which the wave is traveling.

A second form of wave motion, also involving the motion of particles of matter, may be produced by the physical vibration of a body. An example of this type wave is the sound wave which is produced by striking the tine of a tuning fork. When struck, the tuning fork sets up a vibratory motion. As the tine moves in an outward direction, the air immediately in front of the tine is compressed so that its momentary pressure is raised above that at other points in the surrounding medium (air). Because air is elastic, this disturbance is transmitted progessively in an outward direction as a compression wave. When the tine returns and moves in the inward direction, the air in front of the tine is rarefied so that its momentary pressure is reduced below that at other points in the surrounding medium. This disturbance is also transmitted, but in the form of a rarefaction (expansion) wave, and follows the compression wave through the medium.

The compression and expansion waves are also called longitudinal waves, because the particles of matter which comprise the medium move back and forth longitudinally in the direction of wave travel. Figure 4-7 is a simplified representation of the use of a tuning fork to produce a longitudinal wave. The transverse wave shown below the longitudinal wave is merely a convenient device to indicate

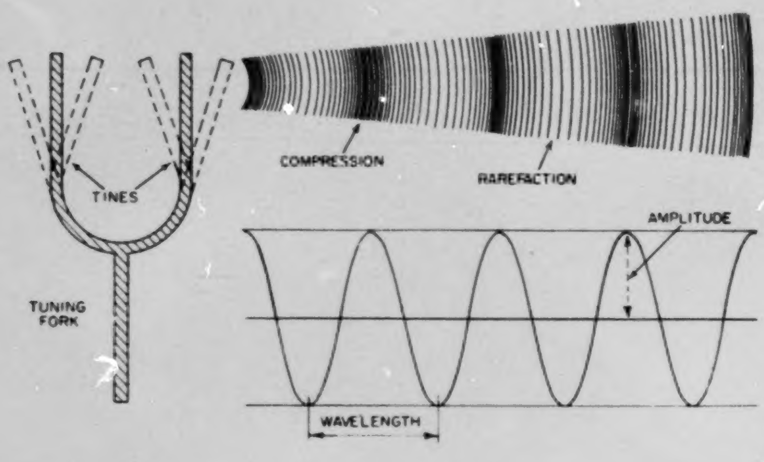

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Figure 4-7.—Compression and rarefaction (expansion) of a sound wave.

the relative density of the particles in the medium, and does not reflect the movement of the particles.

The progress of any wave requiring movement of particles in the transmission medium involves two distinct motions: the wave itself moves forward with constant speed, and simultaneously the particles within the medium vibrate. The period of a vibrating particle is the time (t, in seconds) required for the particle to complete one full vibration or cycle. The frequency (f) is the number of vibrations completed per unit of time and is expressed in hertz. The period is the reciprocal of the frequency ($t=1/f$). The amplitude of vibration is the maximum variation of particle density from the equilibrium density.

A body vibrating at a definite rate produces a disturbance that moves away as a wave in the surrounding medium. The velocity of this wave is equal to the wavelength divided by the period. Since the period is the reciprocal of the frequency, the velocity may be expressed as

$$v = f\ \lambda$$

where v is the velocity of transmission of the wave in the given medium, f is the frequency in hertz, and λ is the wavelength in compatible units of measure. The velocity of transmission may also be described as representing the distance that a wave travels during one period.

Two particles are in phase when they are vibrating with the same frequency, and continually pass through corresponding points of their paths at the same time. For any other condition, the particles are out of phase. Two particles are in phase opposition when they reach their maximum displacements in opposite directions at the same time.

A third type of wave, the electromagnetic wave, does not involve moving particles of matter, but relies on electric and magnetic force fields. The waves previously discussed cannot be transmitted in the absence of a conducting medium–electromagnetic waves are transmitted most efficiently in the absence of matter. In the electromagnetic wave, two components are required–an electric field and a magnetic field. These two fields are mutually perpendicular to each other and to the direction of transmission. In the particle waves, the velocity of transmission varies with the particular medium, and is comparatively very slow; in the electromagnetic wave, the velocity of transmission is the speed of light (approximately 186,300 miles per second). Examples of electromagnetic waves include heat, light, radio waves, X-rays, cosmic radiations, ultraviolet rays, etc.

All three types of wave motion obey certain common laws and have certain common characteristics: All are periodic; that is, they all constantly repeat the same pattern so that each succeeding wave is the same as the previous one. Each wave displays the same relationships of wavelength, frequency, period, velocity of transmission, amplitude, and phase; and each is subject to the same conditions of reflection and refraction. In the electromagnetic wave, the maxima and minima are correlated with field intensity rather than with particle density or displacement as in the case of the other waves. In the longitudinal wave, the density is related to particle density; in the electromagnetic wave, density is related to the strength of the electric and magnetic fields. In the electromagnetic wave, the electric field and the magnetic field are in phase with each other.

A wavelength (a complete cycle) is the distance from one point to the next identical point on the wave. (See fig. 4-7.) The wavelength could start at any point but is usually started on the axis.

A line drawn from the source to any point on one of the waves is called a RAY, and indicates the path over which the wave progresses. Although rays do not actually exist, they are frequently used in illustrations as a convenient method of denoting wave transmission. A wavefront is a surface on which all points are in phase. Wavefronts near the source are sharply curved, while those at a distance are almost flat; individual rays from a distant source are considered to be parallel.

REFLECTION

Within a uniform medium, a ray travels in a straight line. Only at the boundary of two media or in an area where the density of the medium changes do the rays change their direction. When an advancing wavefront encounters a medium of different characteristics, some of its energy is reflected back into the initial medium, and some is transmitted into the second medium. When a wavefront encounters a medium which it cannot penetrate, the wave is reflected from the surface.

REFLECTED waves are simply those waves that are neither transmitted nor absorbed, but are thrown back from the surface of the medium they encounter. If a ray is directed against a reflecting surface, the ray striking the surface is called the INCIDENT ray, and the one that bounces back is the REFLECTED ray. An imaginary line perpendicular to the reflecting surface at the point of impact of the incident ray is called the NORMAL. The angle between the incident ray and the normal is called the ANGLE OF INCIDENCE; the angle between the reflected ray and the normal is the ANGLE OF REFLECTION. These terms are illustrated in figure 4-8.

If the surface of the medium contacted by the incident ray is smooth and polished (as a mirror), each reflected ray will be thrown back at the same angle as the incident ray. The path of the ray reflected from the surface forms an angle exactly equal to the one formed by its path in reaching the medium. This conforms to the law of reflection which states: The angle of incidence is equal to the angle of reflection.

Diffusion

Reflection from a relatively smooth surface presents few problems. As shown in figure 4-9(A), rays are reflected from a flat smooth surface in an orderly manner with all rays at the same angle and all rays parallel to each other. This is called regular or specular reflection. It is a different matter, however, with a rough surface. The law of reflection is still valid; but due to the rough surface, the angle of incidence is somewhat different for each ray. The reflected rays scatter in all directions, as shown in figure 4-9(B). This form of reflection is called irregular or diffused reflection.

Focusing

In addition to reflection from a flat surface and diffusion from a rough one, waves may also be focused by reflection from a curved surface. If the reflecting surface is concave, the parallel rays striking its surface are reflected as shown in figure 4-10(A). The normal is perpendicular to

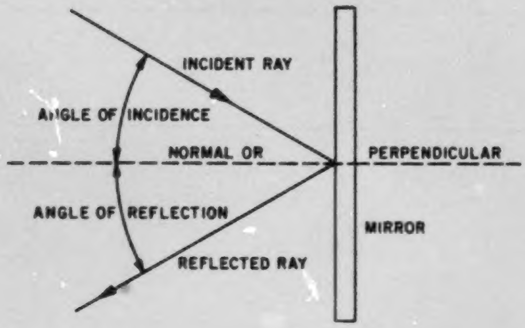

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Figure 4-8.—Terms used to describe the reflection of waves.

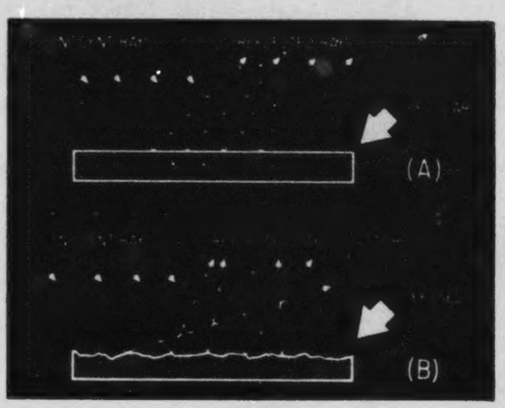

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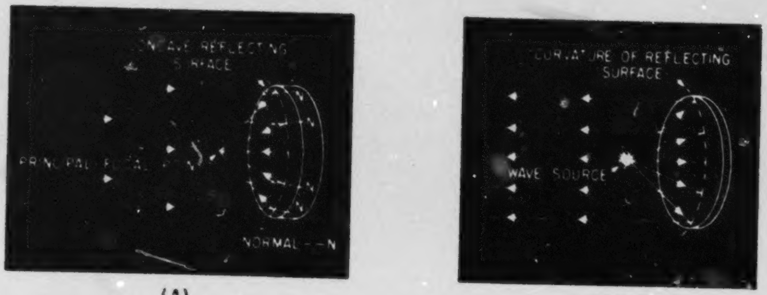
Figure 4-9.—Reflection from a plane surface (A) regular (specular); (B) irregular (diffused).


CONCAVE REFLECTING SURFACE
PRINCIPAL FOCAL POINT
N
NORMAL - - N
CURVATURE OF REFLECTING SURFACE
WAVE SOURCE

(A)

(B)

227.94

Figure 4-10.—Reflection from a concave surface. (A) focusing; (B) illumination.

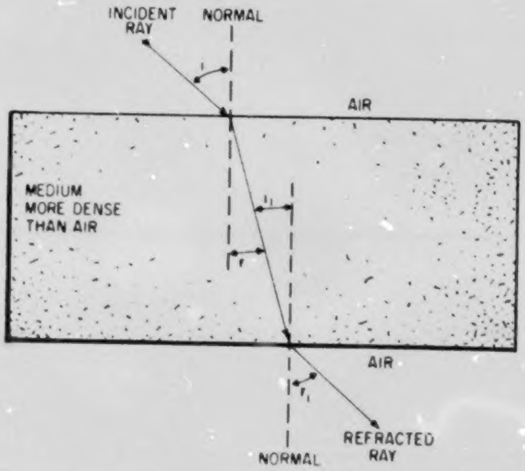
the surface; therefore, the normals on a curved surface are not parallel to one another. The rays come together, or converge, at some point called the focal point. The location of the focal point depends on the rate of curvature of the reflecting surface.

Illumination

If a point source of waves is located at the focal point of the concave reflector, the reflected rays are formed into a narrow beam, with all reflected rays parallel to one another. This condition is illustrated in figure 4-10(B). In this manner, the intensity is increased (or the area is "illuminated"), because rays that would normally be lost are directed into the beam along with the direct rays.

REFRACTION

The change of direction which occurs when a ray passes from one medium into another of different density is called REFRACTION. It is due to the fact that waves travel at various speeds in different transmission media. Refraction always follows a general rule: When a ray passes from one medium into another of greater density, refraction is toward the normal; when passing into a medium of lesser density, refraction is away from the normal. This is illustrated in figure 4-11.


INCIDENT RAY
NORMAL
i
AIR
MEDIUM MORE DENSE THAN AIR
i₁
r
AIR
r₁
NORMAL
REFRACTED RAY

227.95

Figure 4-11.—Refraction of a wave.

SOUND

BASIC CONSIDERATIONS

The term sound as generally used refers to hearing; but when used in physics, the term has to do with a particular type of wave motion and with the generation, transmission, detection, characteristics, and effects of those waves.

One example of the generation and transmission of sound waves is the tuning fork discussed earlier in this chapter. Any object which moves rapidly to and fro, or which vibrates rapidly in such a manner as to disturb the surrounding medium, may become a sound source. Sound requires three components–a source, a medium for transmission, and a detector. As widely different as sound sources may be, the waves they produce have certain basic characteristics.

Wave Motion

Sound waves are longitudinal-type waves which rely on a physical medium for transmission. Since the waves are transmitted by the compression and rarefaction of particles of matter in the medium, they cannot be transmitted through a vacuum. Sound waves are similar to waves of other types in that they can be reflected, absorbed, or refracted according to the laws previously discussed.

The major differences between the waves of sound and the waves of heat and light are the frequencies, the nature of the wave, and the velocities of wave travel.

Frequencies

Sound waves vary in length; a long wavelength is heard as a low sound, while a short wavelength is heard as a high sound. If the sound is below 15 hertz or above 20,000 hertz, it normally cannot be heard by the human ear. The frequency range over which sound can be heard is called the audible range, and the sounds heard are known as sonics. Sounds below 15 hertz are subsonics; those above 20,000 hertz are ultrasonics.

Conduction Media and Velocity of Transmission

In any uniform medium under given physical conditions, sound travels at a definite speed. In some substances, the velocity of sound is higher than in others. Even in the same medium under different conditions of temperature and pressure, the velocity of sound varies. Density and elasticity of a medium are basic physical properties which govern the velocity of sound.

At a given temperature and pressure, all sound waves travel at the same speed in air, regardless of frequency or wavelength. The speed of sound, however, does increase with temperature at the rate of 2.0 feet per second (fps) per degree centigrade. For practical purposes, the speed of sound in air may be considered 1,100 fps. Refer to table 4-1 for speed of sound in various media at different temperatures.

Table 4-1.—Comparison of velocity of sound in various media

Medium	Temperature (°F)	Velocity (ft/sec)
Air	32	1,087
Air	68	1,127
Fresh water	32	4,629
Fresh water	68	4,805
Salt water	32	4,800
Salt water	68	4,953
Steel	32	16,410
Steel	68	16,850

As previously stated, a sound wave is a compressional wave transmitted through an elastic medium. Sound travels faster through water (4,800 fps) than air (1,087 fps) because the elasticity of water is greater than that of air.

For a fixed temperature, the velocity of sound is constant for any medium and is independent of the period, frequency, or amplitude of the disturbance. Thus, the velocity of sound in air at 0°C (32°F) is 1,087 fps and increases by 2 fps for each degree celsius rise in temperature (1.1 fps for each degree Fahrenheit).

The velocity of sound also varies with a change in altitude. With an increase in altitude, the atmospheric pressure is reduced, and the medium is less dense. Sound waves travel slower in a less dense medium. Therefore, it may be considered that the velocity of sound varies inversely with the altitude.

Characteristics

Numerous terms are used to convey impressions of sounds, including whistle, scream, rumble, and hum. Most of these are classified as noises in contrast to musical tones. The distinction is based on the regularity of the vibrations, the degree of damping, and the ability of the ear to recognize components having a musical sequence.

The ear can distinguish tones that are different in pitch, intensity, or quality. Each of these characteristics is associated with one of the properties of the vibrating source or of the waves that the source produces. Thus, pitch is determined by the number of vibrations per second, intensity by the amplitude of the wave motion, and quality by the number of overtones (harmonics) which the wave contains. A sound wave can best be described by its frequency rather than by its velocity or wavelength, as both the velocity and the wavelength change when the temperature of the air changes.

PITCH.–The term pitch is used to describe the frequency of a sound. The outstanding recognizable difference between the tones produced by two different keys on a piano is a difference in pitch. The pitch of a tone is proportional to the number of compressions and rarefactions received per second, which in turn is determined by the vibration frequency of the sounding source.

Pitch is usually measured by comparison with a standard. The standard tone may be produced by a tuning fork of known frequency or by a siren whose frequency is computed for a particular speed of rotation. By regulating the speed, the pitch of the siren is made equal to that of the tone being measured. The ear can determine this equality directly if the two sources are sounded alternately, or by the elimination of beats by regulating the speed of the siren if the two sources are sounded together.

INTENSITY.–When a bell rings, the sound waves spread out in all directions and the sound is heard in all directions. When a bell is struck lightly, the vibrations are of small amplitude and the sound is weak. A stronger blow produces vibrations of greater amplitude in the bell, and the sound is louder. It is evident that the amplitude of the air vibrations is greater when the amplitude of the vibrations of the source is increased. Hence, the loudness of the sound depends on the amplitude of the vibrations of the sound waves. As the distance from the source increases, the energy in each wave spreads out, and the sound becomes weaker.

The intensity of sound is the energy per unit area per second. In a sound wave of simple harmonic motion, the energy is half kinetic and half potential; half is due to the speed of the particles, and half is due to the compression and rarefaction of the medium. These two energies are 90° out of phase at any instant–that is, when the speed of particle motion is at a maximum, the pressure is normal; and when the pressure is at a maximum or a minimum, the speed of the particles is zero.

The loudness of sound depends upon both intensity and frequency. The intensity of a sound wave in a given medium is proportional to the following 4 quantities:

1. Square of the frequency of vibration.
2. Square of the amplitude.
3. Density of the medium.
4. Velocity of transmission.

At any distance from a point source of sound the intensity of the wave varies inversely as the square of the distance from the source.

As a sound wave advances, variations in pressure occur at all points in the transmitting medium. The greater the pressure variations, the more intense the sound wave will be. It can be shown that the intensity is proportional to the square of the pressure variation regardless of the frequency. Thus, by measuring pressure changes, the intensities of sounds having different frequencies can be compared directly.

QUALITY.–Most sounds and musical notes are not pure tones. They are mixtures of tones of different frequencies. The tones produced by most sources can be represented by composite waves in which the sound of lowest pitch, the fundamental tone, is accompanied by several harmonics or overtones having frequencies that are 2, 3, 4 or more times that of the fundamental frequency. The quality of a tone depends on the number of overtones present and on their frequencies and intensities relative to the fundamental tone. It is this characteristic of difference in quality that distinguishes tones of like pitch and intensity when sounded on different types of musical instruments (piano, organ, violin, etc.).

ACOUSTICS

Acoustics is the science that deals with effects on sound in a certain area. The performance of an announcing system or sound system when used in a room or enclosed space depends on the acoustical characteristics of the enclosure. Sound originating in an enclosed space is partly reflected and partly absorbed by enclosing surfaces such as the walls, ceiling, and floor of a room. This action introduces echoes and reverberations, which may seriously impair the quality or character of the sound.

Acoustical Disturbances

Light is often thought of first whenever reflection is discussed; however, reflection is equally common in other waves. As an example, echoes are caused by reflection of sound waves.

ECHO.–An ECHO is the repetition of a sound caused by the reflections of sound waves. When a surface of a room is situated so that a reflection from it is outstanding, it appears as a distinct echo, and is heard an appreciable interval later than the direct sound. If the surface is concave, it may have a focusing effect and concentrate the reflected sound energy at one locality. Such a reflection may be several levels higher in intensity than the direct sound, and its arrival at a later time may be particularly disturbing. Some possible remedies for this condition are as follows:

1. Cover the offending surface with absorbing material to reduce the intensity of the reflected sound.
2. Change the contour of the offending surface and thus send the reflected sound in another direction.
3. Locate the loudspeaker in a different position.
4. Vary the amplitude or the pitch of the signal.

REVERBERATION is the persistence of sound due to the multiple reflection of sound waves between several surfaces of an enclosure. It is one of the most common acoustical defects of a large enclosure. Its duration varies directly with the time interval between reflections (the size of the enclosure) and inversely with the absorbing efficiency of the reflecting surfaces. The result is an overlapping of the original sound and its images. If excessive, reverberation causes a general confusion that is detrimental to speech intelligibility. The hangar deck of an aircraft carrier is an example of an extremely reverberant area. The volume is large, and the hard steel interior surfaces offer very little absorption to sound.

If a single loudspeaker is mounted in a large reverberant area, such as a hangar deck, the intelligibility directly in front of the loudspeaker is satisfactory. The intelligibility decreases rapidly with an increase of either the distance from the loudspeaker or the angle between the listener and the loudspeaker's sound axis. In other words, sound from a loudspeaker in a reverberant space is composed of direct sound that reaches the listener directly without any reflection, and indirect sound that has received at least one reflection.

Intelligibility under these conditions is related to the ratio of direct sound to indirect sound. As the listener moves away from the loudspeaker, the ratio of direct sound to indirect sound at the listening position decreases, and the intelligibility decreases correspondingly. Hence, in a highly reverberant space the intelligibility decreases with distance from the loudspeaker.

To prevent the sound from becoming unintelligible in a highly reverberant space, several speakers can be installed about the area rather than just one. The power requirements remain the same; one 25-watt speaker could be replaced by 5 speakers, each consuming 5 watts. This would greatly increase the direct-to-indirect sound ratio.

INTERFERENCE.–Two sound waves moving through the same medium at the same time will advance independently, each producing the same disturbance as if it were alone. The resultant of the two waves can be obtained by adding algebraically the ordinates (instantaneous magnitudes) of the component waves.

Two sound waves of the same frequency, in phase with each other and moving in the same direction are additive. The resultant wave is in phase with, and has an amplitude equal to, the sum of the component waves.

Two sound waves of the same frequency, in phase opposition and moving in the same direction, are subtractive. If the component waves have equal amplitudes, the resultant wave is zero. This addition or subtraction of waves is often called interference.

Two sound waves of slightly different frequency and moving in the same direction produce a beat note. If the two waves originate from two vibrating sources at the same point, and the frequency of one wave is one vibration per second greater than that of the other at a particular instant, the sources will produce additive disturbances at some points and subtractive disturbances at some other points on the relative positions of the waves. These changes will continue to occur as long as the sources are kept vibrating.

The resultant wave has a periodic variation in intensity at a frequency equal to the difference between the original frequencies of the component waves. The difference frequency, referred to as the beat frequency, produces a type of pulsating interference particularly noticeable in sound waves. The effect of beat frequency, called beats, produces alternately loud and soft pulses or throbs. The effect is most pronounced when the component waves have equal amplitudes.

STANDING WAVES.–Two sound waves of equal frequency and amplitude moving in opposite directions through the same medium may produce standing waves. Standing waves are set up by the reaction of the two waves on each other. At certain points they are in phase and at other points they are 180° out of phase. Because their amplitudes are equal, when the two waves act in opposition on a particle, the particle remains motionless. At these points in a standing wave, there is no vibration and the points are called nodes. At the points where the two waves reinforce each other they produce maximum vibrations on a particle. These points are called antinodes. The distance between successive nodes (or antinodes) is a half wavelength.

RESONANCE.–Resonance, or sympathetic vibration, is a common problem encountered in acoustics. It is somewhat more serious than some of the other problems discussed, because the possibility exists for damage to equipment. Reverberation and resonance are frequently confused, but they are distinctly different in nature. Reverberation is a result of the reflection of sound waves and of the interaction between the direct and reflected sound. There is only a single source involved. In resonance, however, the offending object becomes a sound source under certain conditions. This may be explained by the following example:

Assume that the natural frequency of vibration of a steel shaft, which is weighted on one end and held firmly on the other, is 25 vibrations per second. Suppose that with the system at rest, a sound wave produces a force which acts on the shaft with a to-and-fro motion 125 times per second. This force sets the system vibrating at 125 vibrations per second. These vibrations would be of a small amplitude because the rod and weight are trying to vibrate at their natural rate of only 25 vibrations per second. During part of the time the system is resisting the driving force. The motion of the system in this case is called a forced vibration.

If the force is slowed from 125 vibrations per second to its natural frequency of 25 vibrations per second, the amplitude of vibration becomes very large. The amplitude will build up to a point where the driving force is enough to overcome the inertia of the system. when these conditions exist, the system is said to be in resonance with the driving force, and sound waves are produced by this vibration.

A common example of resonance is found in a crystal oscillator circuit. When an alternating voltage is applied to a crystal that has the same mechanical (resonant) frequency as the applied voltage, it vibrates and only a small applied voltage is needed to sustain vibration. In turn, the crystal generates a relatively large voltage at its resonant frequency.

HEAT

Heat represents a form of energy; therefore, it must be readily exchangeable with or convertible into other forms of energy. The conversion of mechanical energy into heat through friction has been mentioned previously. When a piece of lead is struck a sharp blow with a hammer, part of the kinetic energy of the hammer is converted into heat. In the core of a transformer, electrical and magnetic energy are exchanged; but due to hysteresis and eddy currents, some of the energy is lost as heat. These are some examples of the unwanted conversions, but there are many instances when the production of heat is desirable. Many devices are used almost exclusively to produce heat.

Regardless of how or why it is produced, heat possesses certain characteristics which make it important to the technician. A knowledge of the nature and behavior of heat may prove helpful in understanding the operation of some types of electrical equipment or in determining the cause of nonoperation or faulty operation of others.

NATURE OF HEAT

There are several theories regarding the nature of heat, none of which satisfactorily explain all the characteristics and properties exhibited by heat. The two theories most commonly included in discussions regarding the nature of heat are the kinetic theory and the radiant energy theory.

In the kinetic theory (mentioned earlier in this chapter), it is assumed that the quantity of heat contained by a body is represented by the total kinetic energy possessed by the molecules of the body.

The radiation theory treats radio waves, heat, and light as the same general form of energy, differing primarily in frequency. Heat is considered as a form of electromagnetic energy involving a specific band of frequencies falling between the radio spectrum and light.

A common method used to produce heat energy is the burning process. Burning is a chemical process in which the fuel unites with oxygen, and a flame is usually produced. The amount of heat liberated per unit mass or per unit volume during complete burning is known as the heat of combustion of a substance. By experiment, scientists have found that each fuel produces a given amount of heat per unit quantity burned.

TRANSFER

There are three methods of heat transfer—conduction, convection, and radiation. In addition to these a phenomenon called absorption is related to the radiation method.

Conduction

The metal handle of a hot pot may burn the hand; a plastic or wooden handle, however, remains relatively cool even though it is in direct contact with the pot. This phenomenon is due to a property of matter known as thermal conductivity. All materials conduct heat—some very readily, some to an almost negligible extent. When heat is applied to a body, the molecules at the point of application become violently agitated, strike the molecules next to them, and cause increased agitation. The process continues until the heat energy is distributed evenly throughout the material. Aluminum and copper are used for cooking pots because they conduct heat very readily to the food being cooked. Wood and plastic are used as handles because they are very poor conductors of heat. As a general rule, metals are the best conductors of heat, although some metals are considerably better than others.

Among solids, there is an extreme range of thermal conductivity. In the original example, the metal handle transmits heat from the pot to the hand, with the possibility of burns. The wooden or plastic handle does not conduct heat very well, so the hand is given some protection. Materials that are extremely poor conductors are called "insulators" and are used to prevent heat transfer. Some examples are the wooden handle of soldering irons, the finely spun glass or rock wool insulation in houses, or the asbestos tape or ribbon wrapping used on steam pipes.

Liquids are generally poorer conductors than metals. In figure 4-12, note that the ice in the bottom of the test tube has not yet melted, although the water at the top is boiling. Water is such a poor heat conductor that the rate of heating the water at the top of the tube is not sufficient to cause rapid melting of the ice at the bottom.

Since thermal conduction is a process by which molecular energy is passed on by actual contact, gases are generally even poorer conductors than liquids because the molecules are farther apart and molecular contact is not so pronounced.

Convection

Convection is the process in which heat is transferred by movement of a hot fluid. For example, an electron tube becomes hotter and hotter until the air surrounding it begins to move. The motion of the air is upward because heated air expands in volume and is forced upward by the denser cool air surrounding it. The upward motion of the heated air carries the heat away from the hot tube by convection. Transfer of heat by convection may be hastened by using a ventilating fan to move the air surrounding a hot object. The rate of cooling a cylinder of an air-cooled engine can also be increased by providing fins to conduct heat away from the hot cylinder. The fins provide large surfaces against which cool air can be blown.

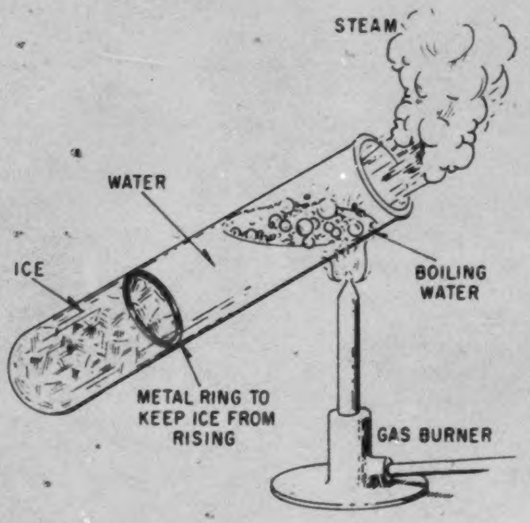


Figure 4-12.–Water is a poor conductor of heat.

A convection process may take place in a liquid as well as in a gas. One example is a transformer in an oil bath. The hot oil is less dense (has less weight per unit volume) and rises, while the cool oil falls, is heated, and rises in turn.

When the circulation of gas or liquid is not rapid enough to remove sufficient heat, fans or pumps may be used to accelerate the motion of the cooling material. In some installations, pumps are used to circulate water or oil to help cool large equipment. Electric fans and blowers are sometime used to aid convection.

Radiation

Conduction and convection cannot wholly account for some of the phenomena that are associated with heat transfer. For example, heating through convection cannot occur in front of an open fire because the air currents are moving toward the fire. It cannot occur through conduction because the conductivity of the air is very low, and the cooler currents of air moving toward the fire would more than overcome the transfer of heat outwardly. Therefore, heat must travel across space by some means other than conduction and convection.

The existence of another process of heat transfer is still more evident when the heat from the sun is considered. Since conduction and convection take place only through molecular contact within some medium, heat from the sun must reach the earth by some other method. (Outer space is an almost perfect vacuum.) Radiation is the name given to this third method by which heat travels from one place to another.

The term radiation refers to the continual emission of energy from the surface of all bodies. This energy is known as radiant energy. It is in the form of electromagnetic waves and is identical in nature with light waves, radio waves, and X-rays, except for a difference in wavelength. Sunlight is a form of radiant heat energy which travels great distances through cold, empty space to reach the earth. These electromagnetic heat waves are absorbed when they come in contact with nontransparent bodies. The net result is that the motion of the molecules in the body is increased, as indicated by an increase in the temperature of the body.

The difference in conduction, convection, and radiation are as follows:

1. Although conduction and convection are extremely slow, radiation takes place with the speed of light. This fact is evident at the time of an eclipse of the sun when the shutting off of the heat from the sun takes place at the same time as the shutting off of the light.
2. Radiant heat may pass through a medium without heating it. For example, the air inside a greenhouse may be much warmer than the glass through which the sun's rays pass.
3. Although conducted or convected heat may travel in roundabout routes, radiant heat always travels in a straight line. For example, radiation can be cut off with a screen placed between the source of heat and the body to be protected.

Absorption

The sun, a fire, and an electric light bulb all radiate energy, but a body need not glow to give off heat. A kettle of hot water or a hot soldering iron radiates heat. If the surface is polished or light in color, less heat is radiated. Bodies which do not reflect are good radiators and good absorbers, and bodies that reflect are poor radiators and poor absorbers. This is the reason white clothing is worn in the summer. A practical example of the control of heat is the Thermos bottle. The flask itself is made of two walls of "silvered" glass with a vacuum between them. The vacuum prevents the loss of heat by conduction and convection, and the "silver" coating prevents the loss of heat by radiation.

The silver-colored bronze paint on the "radiators" in heating systems is used only for decoration and decreases the efficiency of heat transfer. The most effective color for heat transfer is dull black; dull black is the ideal absorber and also the best radiator.

MEASUREMENT OF HEAT

A unit of heat must be defined as the heat necessary to produce some agreed-on standard of change. There are three such units in common use as follows:

1. One British thermal unit (Btu) is the quantity of heat necessary to raise the temperature of 1 pound of water 1°F.
2. One gram-calorie (small calorie) is the quantity of heat necessary to raise 1 gram of water 1°C.
3. One kilogram-calorie (large calorie) is the quantity of heat necessary to raise 1 kilogram of water 1°C. (One kilogram-calorie equals 1,000 gram-calories.) The gram-calorie or small calorie is much more widely used than the kilogram-calorie or large calorie. The large calorie is used in relation to food energy and for measuring comparatively large amounts of heat. Throughout this discussion, unless otherwise stated, the term calorie means gram-calorie. For purposes of conversion, one Btu equals 252 gram-calories or 0.252 kilogram-calorie.

The terms quantity of heat and temperature are commonly misused. The distinction between them should be understood clearly. For example, suppose that two identical pans, containing different amounts of water of the same temperature, are placed over identical gas burner flames for the same length of time. At the end of that time, the smaller amount of water will have reached a higher temperature. Equal amounts of heat have been supplied, but the increase in temperatures is not equal. As another example, suppose that the water in both pans is at the same temperature, say 80°F, and both are to be heated to the boiling point. It is obvious that more heat must be supplied to the larger amount of water. The temperature rise is the same for both pans, but the quantities of heat necessary are different.

Mechanical Equivalent

Mechanical energy is usually expressed in ergs, joules, or foot-pounds. Energy in the form of heat is expressed in calories or in Btus. In a precise experiment in which electric energy is converted into heat in a resistance wire immersed in water, the results show that 4.186 joules equals 1 gram-calorie, or that 778 foot-pounds equals 1 Btu. The following equation is used when converting from the English system to the metric system:

$$1 \text{ Btu} = 252 \text{ calories}$$

Specific Heat

One important way in which substances differ from one another is that they require different quantities of heat to produce the same temperature change in a given mass of substance. The specific heat capacity of a substance is the quantity of heat needed, per unit mass, to increase the temperature 1°C. The specific heat of a substance is the ratio of its specific heat capacity to the specific heat capacity of water. Specific heat is expressed as a number which, because it is a ratio, has no units and applies to both the English and the metric systems.

Water has a high specific heat capacity. Large bodies of water on the earth keep the air and the surface of the earth at a fairly constant temperature. A great quantity of heat is required to change the temperature of a large lake or river. Therefore, when the temperature of the air falls below that of such bodies of water, they give off large quantities of heat to the air. This process keeps the atmospheric temperature at the surface of the earth from changing very rapidly.

TEMPERATURE

If an object is hot to the touch, it is said to have a "high" temperature; if it is cold to the touch, it has a "low" temperature. In other words, temperature is used as a measure of the hotness or coldness of an object being described. However, hotness and coldness are only relative. For example, on a cold day, metals seem colder to the touch than nonmetals because they conduct heat away from the body more rapidly. Also, upon leaving a warm room, the outside air seems cooler than it really is. Going from the outside cold into a warm room, the room seems warmer than it really is. In other words, the temperature a person feels depends upon the state of his body.

Thermometers

The measurement of temperature is known as THERMOMETRY. Many modern thermometers use liquids in sealed containers. Water was the first liquid used; but because it freezes at 0°C, it could not measure temperature below that point. After much experimentation, scientists decided that the best liquids to use in the construction of thermometers are alcohol and mercury because of the low freezing points of these liquids.

LIQUID THERMOMETERS.–The construction of the common laboratory thermometer gives some idea as to the meaning of a change of 1° in temperature. A bulb is blown at one end of a piece of glass tubing of small bore. The tube and bulb are then filled with the liquid to be used. The temperature of both the liquid and the tube during this process are kept at a point higher than the thermometer will reach in normal usage. The glass tube is then sealed and the thermometer is allowed to cool. During the cooling process, the liquid falls away from the top of the tube and creates a vacuum within the thermometer.

For marking, the thermometer is placed in melting ice. The height of the liquid column is marked as the 0°C point. Next, the thermometer is placed in steam at a pressure of 76 centimeters of mercury, and a mark is made at that point to which the liquid inside rises; that is, the boiling point or the 100°C mark. The space between these two marks is then divided into 100 equal parts. These spacings are known as DEGREES. It is this type of thermometer that is used almost exclusively in laboratory work and in testing equipment. It is known as the CELSIUS thermometer.

In English-speaking countries, the FAHRENHEIT thermometer is commonly used for other than physical or chemical laboratory purposes. The freezing point is marked 32° and the boiling point is marked 212°. The space between these marks is divided into 180 equal parts. These division are degrees Fahrenheit, named after the scientist who made the first thermometer of this type. In the U.S. weather reports and room temperatures are given in degrees Fahrenheit.

TEMPERATURE CONVERSION.–There are two systems of temperature measurement; it is frequently necessary to convert from one to the other. The range on the Celsius thermometer from the freezing point to the boiling point is 100°C, and the same range on the Fahrenheit thermometer is 180°F. Thus, over the same temperature range, the liquid moves 180 divisions on the Fahrenheit scale for every 100 divisions on the Celsius scale. A change of 5° on the Celsius scale, therefore, is equal to a change of 9° on the Fahrenheit scale. (The ratio 100/180 reduces to 5/9.) Because zero on the Celsius scale corresponds to 32° on the Fahrenheit scale, a difference in reference points exists between the two scales. (See fig. 4-13.)

To convert from the Fahrenheit scale to the Celsius scale, subtract the 32° difference and multiply the result by 5/9. As an example, convert 68° Fahrenheit to Celsius–

$$\frac{5}{9}(68 - 32)$$

$$\frac{5}{9} \times 36 = 20°\text{C}$$

To convert Celsius to Fahrenheit, the reverse procedure is necessary. First multiply the reading on the Celsius thermometer by 9/5 and then add 32 to the result–

$$\frac{9}{5}(20) + 32$$

$$36 + 32 = 68°\text{F}$$

One way to remember when to use 9/5 and when to use 5/9 is to keep in mind that the Fahrenheit scale has more divisions than the Celsius scale. In going from Celsius to Fahrenheit, multiply by the ratio that is larger; in going from Fahrenheit to Celsius, use the smaller ratio.

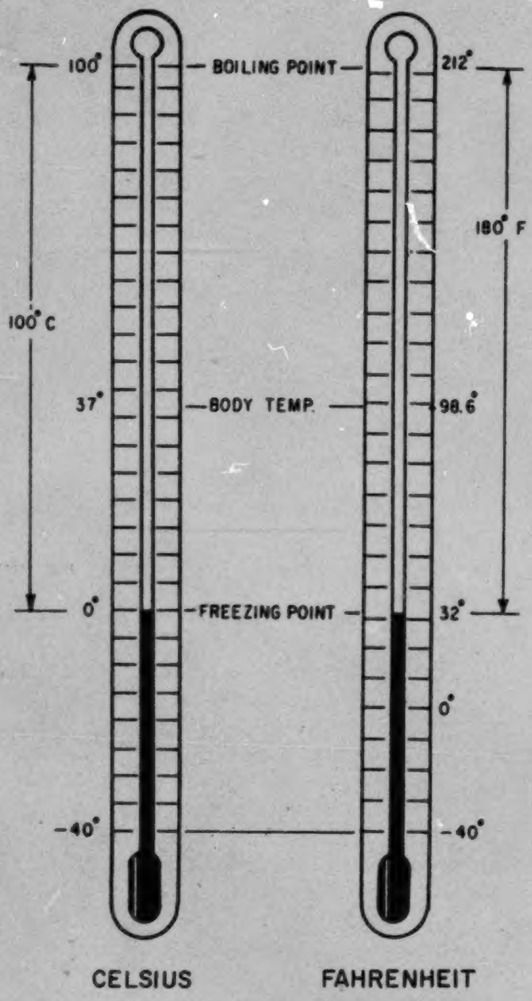


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Figure 4-13.–Fahrenheit and Celsius thermometers.

Another method of temperature conversion which uses these same ratios is based on the fact that the Fahrenheit and Celsius scales both register the same temperature at -40°; that is, -40°F equals -40°C. This method of conversion, sometimes called the "40 rule," proceeds as follows:

1. Add 40 to the temperature which is to be converted. Do this whether the given temperature is Fahrenheit or Celsius.
2. Multiply by 9/5 when changing Celsius to Fahrenheit; by 5/9 when changing Fahrenheit to Celsius.
3. Subtract 40 from the result of step 2. This is the answer.

As an example to show how the 40 rule is used, convert 100°C to the equivalent Fahrenheit temperature:

$$100 + 40 = 140$$

$$140 \times 9/5 = 252$$

$$252 - 40 = 212$$

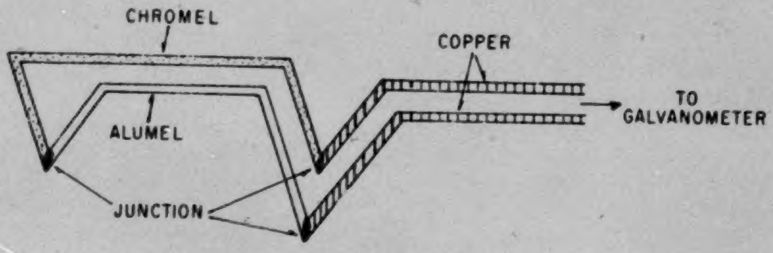
Therefore, 100°C = 212°F. Remember that the multiplying ratio for converting F to C is 5/9, rather than 9/5. Also remember to always ADD 40 first, then multiply, then SUBTRACT 40, regardless of the direction of the conversion.

It is important that all technicians be able to read thermometers and to convert from one scale to the other. In some types of aviation support equipment, the thermometers are provided as a check on operating temperatures. Thermometers are also used to check the temperature of a charging battery.

SOLID THERMOMETERS.–Because the range of all liquid thermometers is extremely limited, other methods of thermometry are necessary. Most liquids freeze at temperature between 0° and -200° Celsius. At the upper end of the temperature range where high heat levels are encountered, the use of liquid thermometers is limited by the high vapor pressures of those liquids. Among the most widely used types of thermometers other than the standard liquid thermometers are the resistance thermometer and the thermocouple.

The RESISTANCE THERMOMETER makes use of the fact that the resistance of metals changes as the temperature changes. (Refer to *Basic Electricity,* NAVEDTRA 10086 (Series.) This type thermometer is usually constructed of platinum wire wound on a mica form and enclosed in a thin-walled silver tube. It is extremely accurate from the lowest temperature to the melting point of the unit.

The THERMOCOUPLE shown in figure 4-14 is essentially an electric circuit. Its operation is based on the principle that when two unlike metals are joined and the junction is at a different temperature from the remainder of the circuit, an electromotive force is produced. This electromotive force can be measured with great accuracy by a galvanometer. Thermocouples can be located wherever measurement of the temperature is important and wires run to a galvanometer located at any convenient point. By means of a rotary selector switch, one galvanometer can read the temperature at any of a number of widely separated points.



228.33

Figure 4-14.–Thermocouple.

Thermal Expansion

Nearly all substances expand or increase in size when their temperature increases. Railroad tracks are laid with small gaps between the sections to prevent buckling when the temperature increases in summer. Concrete pavement has strips of soft material inserted at intervals to prevent buckling when the sun heats the roadway. A steel building or bridge is put together with red-hot rivets so that when the rivets cool they will shrink and the separate pieces will be pulled together very tightly.

As a substance is expanded by heat, the weight per unit volume decreases. The reason is that the weight of the substance remains the same while the volume is increased by the application of heat. Thus the density decreases with an increase in temperature.

Experiments show that for a given change in temperature, the change in length or volume is different for each substance. For example, a given change in temperature causes a piece of copper to expand nearly twice as much as a piece of glass of the same size and shape. For this reason, the lead wires into an electronic tube cannot be made of copper but must be made of a metal that expands at the same rate as glass. If the metal does not expand at the same rate as the glass, the vacuum in the tube is broken by air leaking past the wires in the glass stem. The metal usually used for this purpose is an alloy called "Covar."

The amount that a unit length of any substance expands for a 1° rise in temperature is known as the coefficient of linear expansion for that substance.

COEFFICIENTS OF EXPANSION.–To estimate the expansion of any object, such as a steel rail, it is necessary to know three things about it–its length, the rise in temperature to which it is subjected, and its rate or coefficient of expansion. The amount of expansion is expressed by the following equation:

expansion = coefficient x length

x rise in temperature

$$e = kl\,(t_2 - t_1)$$

In this equation, the letter k represents the coefficient of expansion for the particular substance. In some instances, the Greek letter α (alpha) is used to indicate the coefficient of linear expansion.

PROBLEM: If a steel rod measures exactly 9 feet at 21°C, what is its length at 55°C? (The coefficient of linear expansion for steel is 10×10^{-6}.) If the equation $e = kl\,(t_2 - t_1)$ is used, then

$$e = (10 \times 10^{-6}) \times 9 \times (55 - 21)$$

$$e = 0.000010 \times 9 \times 34$$

$$e = 0.00306$$

This amount, when added to the original length of the rod, makes the rod 9.00306 feet long. (Since the temperature has increased, the rod is longer by the amount of e. If the temperature had been lowered, the rod would have become shorter by a corresponding amount.)

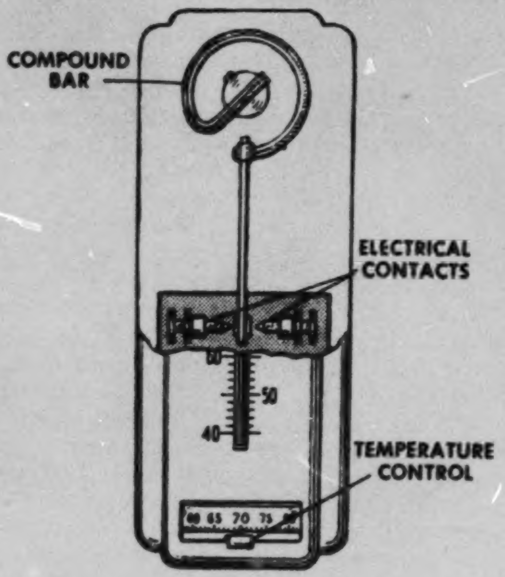
The increase in the length of the rod is relatively small; but if the rod were placed where it could not expand freely, there would be a tremendous force exerted due to thermal expansion. Thus, thermal expansion must be taken into consideration when designing ships, buildings, and all forms of machinery.

Since the coefficient of linear expansion is defined as the change in unit length, its value does not depend upon any particular length unit. Its value, however, does depend upon the size of the degree used to measure the temperature change. Table 4-2 gives the value of the coefficient of linear expansion of several substances per Celsius degree. The coefficient of expansion per Fahrenheit degree will be just 5/9 as much.

A practical application for the difference in the coefficients of linear expansion is the thermostat. This instrument comprises two strips of dissimilar metal fastened together. When the temperature changes, a bending takes place due to the unequal expansion of the metals, (fig. 4-15). Thermostats are used in overload relays for motors, in temperature-sensitive switches, and in electric ovens. (See fig. 4-16.)

Table 4-2.–Expansion coefficients (per Celsius degree)

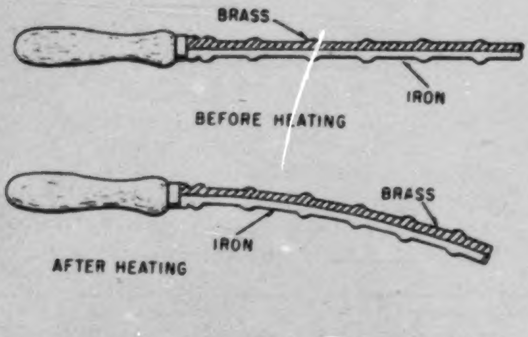
Substance	Coefficient of linear expansion
Aluminum	24×10^{-6}
Brass	20×10^{-6}
Copper	14×10^{-6}
Glass	$4 \text{ to } 9 \times 10^{-6}$
Covar	$4 \text{ to } 9 \times 10^{-6}$
Steel	10×10^{-6}
Quartz	0.4×10^{-6}
Zinc	26×10^{-6}



243.19

Figure 4-16.–Thermostat.

The coefficient of surface or area expansion is approximately twice the coefficient of linear expansion. The coefficient of volume expansion is approximately three times the coefficient of linear expansion. It is interesting to note that in a plate containing a hole, the area of the hole expands at the same rate as the surrounding material. In the case of a volume enclosed by a thin solid wall, the volume expands at the same rate as would a solid body of the material of which the walls are made.



243.18

Figure 4-15.–Compound bar.

CHANGE OF STATE

A thermometer placed in melting snow behaves in a strange manner. The temperature of the snow rises slowly until it reaches 0°C. Provided that the mixture is stirred constantly, it remains at that point until all the snow has changed to water; when all the snow has melted, the temperature again begins to rise. A definite amount of heat is required to change the snow to water at the same temperature. This heat is required to change the water from crystal form to liquid form.

Heat of Fusion

Eighty gram-calories of heat are required to change 1 gram of ice at 0°C to water at 0°C. In English units, the heat required to change 1 pound of ice at 32°F to water at 32°F is 144

Btus. These values are called the HEAT OF FUSION of water. The heat used while the ice is melting represents the work done to produce the change of state. Since 80 calories are required to change a gram of ice to water at 0°C, when a gram of water is frozen it gives up 80 calories.

Many substances behave very much like water. At a given pressure, they have a definite heat of fusion and an exact melting point. There are many materials, however, which do not change from a liquid to a solid state at one temperature. Molasses, for example, becomes thicker and thicker as the temperature decreases; but there is no exact temperature at which the change of state occurs. Wax, celluloid, clay, and glass are other substances which do not change from a liquid to a solid state at any particular temperature. In fact, measurements of the glass thickness at the bottom of windows in ancient cathedrals tend to indicate that the glass is still flowing at an extremely slow rate. Most types of solder used in electrical maintenance also tend to become mushy before melting.

Heat of Vaporization

Damp clothing dries rapidly under a hot flat-iron but not under a cold one. A pool of water evaporates more rapidly in the sun than in the shade. Thus, it may be concluded that heat has something to do with evaporation. The process of changing a liquid to a vapor is similar to that which occurs when a solid melts.

If a given quantity of water is heated until it evaporates–that is, changes to a gas (vapor)–a much greater amount of heat is used than that which is necessary to raise the same amount of water to the boiling point. For example, several hundred calories are required to change 1 gram of water to vapor at a given temperature. It takes 972 Btus to change 1 pound of water at 212°F to water vapor (steam) at 212°F. The amount of heat necessary for this change is called the LATENT HEAT OF VAPORIZATION of water. Over five times as much heat is required to change a given amount of water to vapor than to raise the same amount of water from the freezing to the boiling point.

BOILING.–When water is heated, some vapor forms before the boiling point is reached. The change from water to vapor occurs as follows: As the water molecules take up more and more energy from the heating source, their kinetic energy increases. The motion resulting from the high kinetic energy of the water molecules causes a pressure which is called the vapor pressure. As the velocity of the molecules increases, the vapor pressure increases. At sea level, atmospheric pressure is normally 29.92 inches of mercury. The boiling point of a liquid is that temperature at which the vapor pressure equals the external or atmospheric pressure. At normal atmospheric pressure at sea level, the boiling point of water is 100°C or 212°F.

While the water is below the boiling point, a number of molecules acquire enough kinetic energy to break away from the liquid state into vapor. For this reason some evaporation slowly takes place below the boiling point. At the boiling point or above, large numbers of molecules have enough energy to change from liquid to vapor and the evaporation takes place much more rapidly.

If the molecules of water are changing to water vapor in an open space, the air currents carry them away quickly. In a closed container, they rapidly become crowded and some of them bounce back into the liquid as a result of collisions. When as many molecules are returning to the liquid state as are leaving it, the vapor is said to be saturated. Experiments have shown that saturated vapor in a closed container exerts a pressure and has a given density at every temperature.

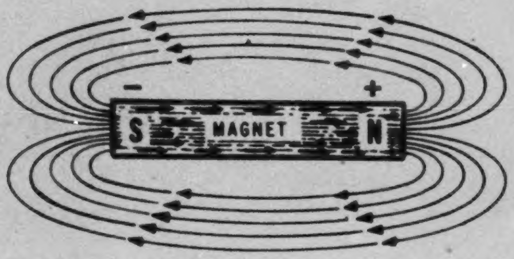
ELECTRICITY

The following discussion is intended as an introduction only. For further details concerning specific topics, trainees are urged to review *Basic Electricity*, NAVEDTRA 10086 (Series), as outlined in the following list:

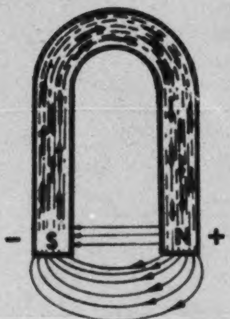
1. Conductivity–chapter 2.
2. Magnetism–chapter 8.
3. Instruments–chapter 15.
4. Generators–chapters 16 and 18.

VOLTAGE PRODUCED BY MAGNETISM

A magnet has lines of force between the poles (fig. 4-17). These lines of force are in a definite direction and essentially complete the circuit of the lines of force that travel through the metal of the magnet to the north pole of the magnet. Since there is no metal for a complete circuit, the lines of magnetic force travel through the air to the south pole of the magnet, completing the circuit. Magnetic flux is the entire quantity of magnetic lines surrounding a magnet. Flux in a magnetic field circuit corresponds to current in an electrical circuit, though magnetism itself is not a stream of particles in motion as is a current of electricity but is a field of force in space.



BAR MAGNET
(A)



HORSESHOE MAGNET
(B)

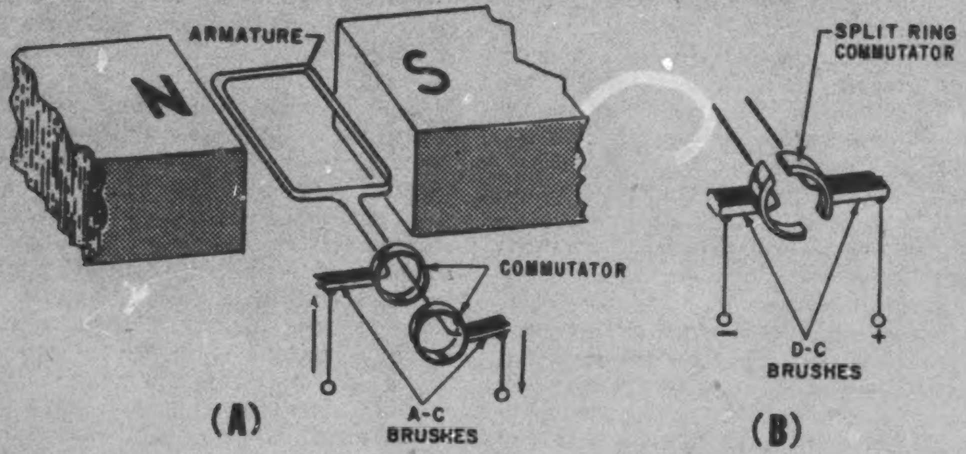
227.19

Figure 4-17.—Magnetic lines of force.

When a conductor cuts (moves across) the lines of force of a magnet, a current of electricity is produced in the conductor. This is called magnetic induction. In an automobile generator, this principle is used to produce electricity to fire the spark plugs, charge the battery, and operate the electrical system. The outside of the generator is an electromagnet which has a magnetic field (an electromagnet is a magnet produced by an electric current). The inside of the generator (armature) is turned by mechanical means and cuts the magnetic lines of force creating a current. This current is carried from the armature by brushes that are stationary but in contact with the rotating commutator.

In figure 4-18 (A), the commutator is made up of two solid rings. As the armature turns, each wire in it moves up across the magnetic field at one instant; and as the armature completes one revolution, it then moves down through the field the next instant, causing the current to flow first in one direction and then in the opposite direction. This is alternating current (ac). In figure 4-18 (B) the commutator is of the split ring type, so positioned that when the wires in the armature rotate within the magnetic field only half of the produced current is delivered. Then, instead of the current changing direction as it does in an alternating-current generator, it leaves the direct-current generator as a steady (nonreversing) flow of electricity or direct current (dc).

Some of the electric current is used to recharge the lead-acid battery. The battery consists of three or more wet cells connected together in a container. Through chemical action within the battery, an electric current is produced. This electricity is used to start the engine. After the engine is started, the generator supplies electricity to fire the spark plugs of the gasoline engine and operate the electric system. Some of the current from the generator enters the battery in a reverse direction from the battery-produced current and reverses the chemical action within the battery so that the battery can again produce enough electrical current for the needs of the engine and associated systems. A voltage regulator controls the input of current from the generator to the battery so that only enough current enters the



227.20

Figure 4-18.—(A) Alternating current generator; (B) direct-current generator commutator.

battery to complete the reverse chemical action and not enough to overcharge the battery and cause damage to it.

ELECTRIC CURRENT AND CONDUCTORS

In the early part of this chapter, the electric balance of an atom was explained. This will be used as a basis to determine how an electric current is carried by a conductor.

When an electric current, as produced by a generator, is applied to an electric conductor (such as a copper wire), electrons in the outer orbits of the copper atoms are forced out of orbit. Each electron moves a short distance to the neighboring atom where it replaces an electron of this neighboring atom by forcing it out of its orbit. This happens to most of the atoms of copper in the end of the copper wire where the current is induced. The replaced electrons repeat the process to other atoms along the wire until the movement is transmitted through the entire length of the wire conductor, thereby carrying the current the length of the wire.

The greater the number of electrons in a material that can be made to move under the application of an induced current, the better are the conductive qualities of that material. Copper wire meets this requirement while not being too costly to produce.

The protons of the atoms of copper do not move to other atoms because they are extremely heavy compared to the electrons of atoms of copper. For example, a proton of the lightest element, hydrogen, is approximately 1,850 times as heavy as a hydrogen electron. Thus, when the electric current is induced into the conductor, it is the light electron that moves the current along the conductor.

An electric circuit is a complete path through which electrons can flow from the negative terminal of the voltage source; through the connecting wires or conductors; through the load or loads; and back to the positive terminal of the voltage source. A circuit is thus made up of a voltage source, the necessary connecting conductors, and the effective load.

In contrast to good conductors such as copper, some materials such as rubber, glass, and dry wood have very few free electrons; therefore, they are poor conductors and are called insulators. There is no sharp division between conductors and insulators because some electron motion exists to some extent in all matter. The best conductors are used to carry current, and the poorest conductors are used as insulators to prevent the current from being diverted from the conductors.

ELECTRICAL MEASURING INSTRUMENTS

The basic electrical measuring instruments are a voltmeter, an ammeter, and an ohmmeter. A voltmeter is used to measure the electromotive force produced by a generator or battery. The electromotive force is the force that causes electrons to move along a conductor as an electric current. For example, a 12-volt battery has the capability of producing 12 volts of electromotive force when new and fully charged. A volt is the electromotive force which will produce a current of 1 ampere when steadily applied to a conductor whose resistance is 1 ohm.

An ammeter measures the rate of flow of electrons through a conductor. An ammeter may be used to determine if the current flow is correct in a circuit when compared to applicable specifications.

An ohmmeter measures the resistance of a conductor to the flow of electricity through it. The ohmmeter may be used to determine if a conductor is complete by an indication of a very low reading (approaching zero resistance). A high resistance reading may indicate an open circuit or dirty or corroded terminal connections.

HYDRAULICS AND PNEUMATICS

Many of the equipments with which the ASM works include systems operated by hydraulic or pneumatic pressure. Although he is not responsible for the maintenance of hydraulic and pneumatic systems, the ASM should be familiar with the units of measure and the terminology associated with these systems. Chapter 2 of *Fluid Power,* NAVEDTRA 16193 (Series), contains introductory material on these topics and is recommended for study.

CHAPTER 5

PUBLICATIONS, MIARS, AND DRAWINGS

PUBLICATIONS

The primary purpose of technical publications is to aid the technician in accomplishing assigned tasks. They are designed to communicate information and directions to him in a specific technical language. They are prepared by the manufacturer of specific equipment and by the Naval Air Systems Command or its field activities in accordance with specifications issued by NAVAIRSYSCOM. They set forth current, authoritative information concerned with material upkeep, check, test, repair, and operation in a manner to provide for optimum product performance. It is extremely important, and therefore mandatory, that all personnel responsible for the operation and maintenance of ground support equipment be thoroughly familiar with these publications and that they use the information contained therein in the daily execution of their technical tasks. The technician or mechanic can no longer properly perform all work without written technical aid. Modern technology is a constantly changing thing and demands continuous reference to and use of the approved technical publications.

Although some technical publications of interest to the ASM are issued by other Naval Commands, such as Naval Facilities Engineering Command and the Naval Sea Systems Command, the majority are issued by the Naval Air Systems Command. The publications issued by NAVAIRSYSCOM are known as aeronautic publications and are grouped into three major classes or groups—those issued in the form of technical manuals, those issued in the form of technical directives, and those issued in the form of engineering drawings and associated data.

When a new item of equipment is accepted by the Navy, manuals necessary to ensure its proper operation and upkeep are prepared and made available to all activities using and/or maintaining the equipment. Supplemental information and other directive-type publications that must be issued from time to time are issued in the form of letter materials. Both manual and letter-type publications may, on occasion, be properly referred to as directives. Broadly speaking, any communication which initiates or governs action, conduct, or procedures is a directive. Another term commonly used to identify manual- and letter-type publications is technical data.

As emphasized throughout this manual, all personnel of the ASM rating must use applicable technical publications in the performance of their duties. This chapter is devoted primarily to the type of information contained in various technical publications relative to the operation, servicing, and maintenance of support equipment.

All aeronautic publications, both manual- and letter-type, are assigned a title and code number. When they are available for issue, all publications, except Instructions and Notices, are listed in the Naval Aeronautic Publications Index. One of the requirements for advancement to ASM2 is to be able to use the different parts of this Index to locate and identify publications relative to the maintenance of support equipment. The contents and use of the Naval Aeronautic Publications Index are discussed in the first part of this chapter.

NAVAL AERONAUTIC PUBLICATIONS INDEX

A complete Naval Aeronautic Publications Index consists of several individual publications, each of which serves a specific purpose. They are identified as follows:

Navy Stock List of Forms and Publications, NAVSUP Publication 2002.

Equipment Applicability List, NAVAIR 00-500A.

Aircraft Application List, NAVAIR 00-500B.

Directives Application List by Aircraft Configuration, NAVAIR 00-500C.

Microfilm Cartridge Cross Reference, NAVAIR 00-500M.

The content and purpose of each of these publications are discussed in the following paragraphs.

Numerical Listing

The Navy Stock List of Publications and Forms, NAVSUP Publication 2002, has been converted to microfiche. With this conversion, the format of the publication has been changed from the printed paper type. The printed, sectionalized NAVSUP 2002, wherein the various sponsoring commands, bureaus, offices, etc. had publications listed in an individual sections and wherein forms were listed in a separate section, has been modified to a three-section microfiche publication as follows:

Section I is an alphabetic/numeric listing of form numbers, publication numbers, hull numbers, and electronic model numbers.

Section II is an alphabetic listing of publications and forms by title/nomenclature.

Section III is a numeric listing of publications and forms by National Stock Number (NSN) followed by NAVAIRSYSCOM technical directives.

Publications and forms are sequenced together. This new microfiche edition is issued quarterly in February, May, August, and November. Each edition reflects all current and available cognizance symbol I and II publications and forms.

The microfiche cards that make up the NAVSUP 2002 are accompanied by a printed paper type of introduction. This introduction is not reissued with each quarterly edition of the microfiche cards but is distributed separately and treated as an individual publication. The introduction to the NAVSUP 2002 contains the following:

1. Requisition instruction for forms and publications.
2. Listings of prefixes and codes used to identify the various types of publications.
3. Standard abbreviations.
4. Identification aids and detail instructions for requisitioning commercial books and publications sponsored by the other service branches and other U. S. Government departments, bureaus, etc.
5. Other detailed information pertaining to the requisitioning of printed material.

Equipment Applicability List

Basically, the Equipment Applicability List, NAVAIR 00-500A, is a cross-reference index listing of NAVAIR manual-type publications according to model/type part number. Since this Index contains several thousand entries, one document would be very cumbersome to use. For this reason, the Index is divided into several volumes. At the time of this writing, there are seven volumes. Each of the first six volumes contains 400 pages, and Volume 7 contains the remaining entries. With the exception of several small sections in the first part of Volume 1, the Equipment Applicability List is one continuous index of Model/type part numbers listed in strict alphanumerical sequence. In addition to an Introduction, the other sections in the first part of Volume 1 pertain primarily to manuals for aircraft, weapons systems, and aircraft engines. Therefore, the publication numbers are listed according to aircraft, aircraft engine, and weapons system designation. Of these sections, the one pertaining to Allowance Lists is most important to the ASM. Allowance Lists are discussed later in this chapter.

The format of the alphanumerical listing is illustrated in figure 5-1. Specific examples of model/type part numbers pertaining to support equipment were selected to illustrate some of the various codes and abbreviated statements

(1)	MODEL/TYPE PART NO.	VENDOR	NOMENCLATURE		NEXT HIGHER ASSEMBLY	SUPPL	REMARKS	SUPPL PART NO. DATA
(2)			TECH DATA NO.	TYPE	TECH DATA STK NO.	AV SC		
(3)	AERO46A	98296	WEAPONS LOADER					
(4)			19-15BE-3	05	0819-008-9000	A		
(5)			19-600-65-6-1	37	0819-042-5000	A		
(6)	AHT63	82386	HYD TEST STAND					EQUAL TO 64A99E1
(7)			17-15BF-39	15	0817-057-6000	A		
(8)			17-600-23-6-1	37	0817-110-8500	A		
(9)			17-600-23-6-4	37	0817-110-9000	A		
(10)	AN6295-1	99999	REGULATOR					
(11)			03-10ABC-504	10	0803-152-5000	A		
(12)			03-30ELE-501	10	0803-360-2000	A		
(13)	A840-0031	82386	TEST STAND					EQUAL TO AHT63
(14)			17-15BF-39	15	0817-057-6000	A		
(15)	B007	36659	PLATFORM SERVICING					SUPS COMPL 918104-1
(16)			19-15-21	12	0819-001-2000	A		
(17)	K54402	88276	DOLLY					
(18)			19-15A-41	04	-- --			
(19)	378782	70210	GAS TURBINE PLUMBING					
(20)			19-105B-15	10	0819-035-4500	A		
(21)	569180	55168	FILTER ASSY					
(22)			UNDER REVIEW		-- --			
(23)	63A109J1	99999	ULTRASONIC CLEANER					
(24)			UNDER PROCUREMENT	15	-- --			
(25)	64A99E1	82386	TEST STAND					EQUAL TO A840-0031
(26)			17-15BF-39	15	0817-057-6000	A		
(27)	682570-1	99193	REFRIGERATION UNIT		378782			
(28)			19-105B-15	10	0819-035-4500	A		
(29)	918104-1	36659	PLATFORM SERVICING					SUPSD COMPL BY B007
(30)			19-15-21	12	0819-001-2000	A		

NOTE: The sequential line numbers--(1), (2), (3), etc.--in the left margin are for explanation purposes only.

225.5

Figure 5-1.—Format of Equipment Applicability List, NAVAIR 00-500A.

used throughout the Index. These entries are discussed in the following paragraphs. A complete list with explanations of all codes and statements used in the Index is contained in the Introduction, located in the first part of Volume 1. This Introduction also contains other valuable information concerning the use of the Index. It is important that all users of this Index thoroughly study this section and become familiar with its contents.

NOTE: It must be emphasized that the entries in figure 5-1 were selected to illustrate the format and use of the Equipment Applicability List. Although the information concerning these entries was current at the time of this writing, all or any part of it is subject to change from time to time. Therefore, the latest edition and supplement (discussed later) of the Equipment Applicability List must be consulted in all cases.

The column headings of the Equipment Applicability List consist of two lines. (See lines (1) and (2) of figure 5-1.) Line (1) pertains to information about the specific item of equipment. This information is listed under the appropriate headings in the line corresponding to the model/type part number, as shown in lines (3), (6), (10), (13), etc. The headings in line (2) pertain to the status of publications for each model/type part number. This information is listed on a line, or lines, under the information concerning the model/type part number. For example, the information listed in lines (4) and (5) corresponds to the headings in line (2) and pertains to the publications for the AERO46A Weapons Loader listed in line (3).

The type of information listed under each column heading is discussed in the following paragraphs.

MODEL/TYPE PART NO.–The identifying number of the specific item of equipment or system is listed in this column. Some items of equipment are identified by more than one part number. In these cases, all of the identifying numbers are listed with each number in alphanumerical sequence. For example, the numbers listed in this column on lines (6), (13), and (25) are different numbers for the same hydraulic test stand. AHT63 is the model number, A840-0031 is the manufacturer's part number, and 64A99E1 is the Navy part number.

VENDOR.–The appropriate five-digit code which identifies the contractor or government agency that manufactured the item of equipment is listed in this column. Cataloging Handbooks H4-1 and H4-2 should be referred to for the interpretation of these codes. If a vendor code is not firmly established at the time the item of equipment is listed in the Index, the code 99999 is inserted. (See lines (10) and (23) in figure 5-1.) As these vendor codes are established, appropriate changes will be made in subsequent issues of this Index.

NOMENCLATURE.–A brief description of the item of equipment is listed in this column. The examples (WEAPONS LOADER, HYD TEST STAND, etc.) illustrated in figure 5-1 are typical of the descriptions used throughout the Index.

NEXT HIGHER ASSEMBLY.–In some cases, technical manuals are not required for a specific item of equipment because the necessary information is, or will be, included in the technical manual(s) for the next higher assembly. In these instances, the model/type part number of the next higher assembly is listed in this column. For example, the required information for the Refrigeration Unit listed in line (27) of figure 5-1 is included in the publication for the Gas Turbine Plumbing listed in line (19). As illustrated in line (27), the part number (378782) of the Gas Turbine Plumbing is listed in the NEXT HIGHER ASSEMBLY column.

SUPPL REMARKS (Supplemental Remarks).–An entry is included in this column if the number listed under the MODEL/TYPE PART NO. is supplemented with other part number information. The descriptive statements EQUAL TO in lines (6), (13), and (25), SUPS COMPL (supersedes completely) in line (15), and SUPSD COMPL BY (superseded completely by) in line (29) are examples of the entries listed in this column. Other entries sometimes listed in this column are INTERCHANGEABLE, SUPSD PART BY (superseded partially by), and SUPS PART (supersedes partially).

SUPPL PART NO. DATA (Supplemental Part Number Data).–A part number listed in this column is associated with the statement listed in the SUPPL REMARKS column. Examples of this type entry are illustrated in lines (6), (13), (15), (25), and (29). Refer to the numbers listed in this column on lines (6), (13), and (25). As explained previously, these are different numbers for the same hydraulic test stand. Although there are three different numbers, only one is listed in each space. It should be noted, however, that regardless of which number the user of the Equipment Applicability List looks up first, he will be directed systematically through all three part numbers. For example, assume that the only number an ASM has available for this hydraulic test stand is 64A99E1. When he locates this number in the Index, he is referred to part number A840-0031. By locating this number, he is referred to AHT63. When he locates AHT63 he is referred again to the original part number, 64A99E1. This type of arrangement is used throughout the Equipment Applicability List when two or more numbers are listed for the same item of equipment.

TECH DATA NO. (Technical Data Number).–The applicable current technical manual and all proposed technical manuals (those which have been numbered but have not been published) are listed in this column. The technical manuals are listed by code number as illustrated by all entries in this column of figure 5-1 with the exceptions on lines (22) and (24). (The numbering system (code numbers) for technical manuals is discussed later in this chapter.) If the technical manual numbers have not been assigned, or it has not been determined if technical manuals will be procured, or if coverage will not be contained in a NAVAIR technical manual, a qualifying statement is entered in this column. For example: the statement UNDER REVIEW, in line (22) means that the part number has been submitted to the Naval Air Technical Services Facility (NATSF) for possible action, but no decision has been made prior to the date of the current issue of the Index. The statement, UNDER PROCUREMENT, listed in line (24) indicates that publications are being procured for this item of equipment but the publication numbers have not been assigned. The Introduction in the first part of Volume 1 of the Index should be consulted for explanations of other qualifying statements used in this column.

TYPE.–A code, which corresponds to the type of technical manual, is listed in this column. For example, the number 05 in line (4) is the code for Operation and Service Instructions Manuals, and the number 37 in line (5) is the code for Maintenance Requirements Cards for Ground Support. Since the use of these particular codes is limited to the Equipment Applicability List, a complete list of the different types of manuals and their corresponding codes is listed in the Introduction in Volume 1. The different types of technical manuals applicable to the maintenance of support equipment are discussed later in this chapter.

TECH DATA STK NO. (Technical Data Stock Number.–The National Stock Number for ordering the publication is listed in this column.

AV (Availability Code).–The letter "A" in this column indicates the technical manual is available and may be requisitioned from the supply system by using the applicable stock number. Before ordering, the Numerical Index, NAVSUP 2002 microfiche, and its latest supplement should be checked for the complete publication title, date, and requisition restriction code. A blank space in this column indicates the technical manual is not available as of the date of the current Index and no attempt should be made to order this manual from the supply system.

SC (Security Classification).–Technical manuals listed are unclassified unless the letter C (Confidential) or the letter S(Secret) is listed in this space.

Aircraft Application List

The Aircraft Application List, NAVAIR 00-500B, contains a listing of Naval Air Systems Command technical manuals grouped according to their application to an aircraft. The aircraft are arranged by model number and are grouped in series according to their mission (Attack Series, Cargo/Transport Series, Fighter Series, etc.). The applicable technical manuals are listed by code number under each model of aircraft. The manuals are grouped in numerical sequence according to the General Classification numbers listed in table 5-1. The groups include the 00, 01, 02, 03, 05, 11, 13, 08 & 16, 17, & 18, and 19 series. Groups 00 (Allowance Lists), 17 & 18 (Machinery, Tool, and Test Equipment), and 19 (Ground Servicing and Automotive Equipment) are of most interest to the ASM.

The Aircraft Application List is especially useful for determining what manuals are available for a particular model aircraft. A listing of basic numbering categories is provided in the first few pages of the list. This listing may be used in determining the general type of equipment covered in the publication. For determining the specific item of equipment

Table 5-1.—General subject classification numbers for manual-type publications

General	00
Aircraft	01
Powerplants	02
Accessories	03
Aircraft Hardware and Rubber Material	04
Instruments	05
Fuels, Lubricants, and Gases	06
Dopes and Paints	07
Electronics	08 (also 16)
Instructional Equipment and Training Aids	09 (also 01 and 28)
Photography	10
Aviation Armament	11
Fuel and Oil Handling Equipment	12
Parachute and Personal Survival Equipment	13
Hangar and Flying Field Equipment	14
Standard Preservation and Packaging Instructions	15
Electronics	16 (also 08)
Machinery, Tools, and Test Equipment	17 (also 18)
Ground Servicing and Automotive Equipment	19 (also 08, 20, and 14)
Descriptive Data Sheets for Aviation Support Equipment	20
Chemical Equipment	24
Meteorology DCNO (AIR)	50
Ship Installations	51

covered by a publication and the title of the publication, reference should be made to Section 1 of NAVSUP 2002.

Directives Application List

Basically, the Directives Application List by Aircraft Configuration, NAVAIR 00-500C, is a listing of the active Naval Air Systems Command letter type technical directives (Bulletins and Changes) with respect to their applicability to an aircraft. It serves the same purpose for letter-type technical directives as the Aircraft Application List does for technical manuals. The applicable technical directives are listed, by number, under each configuration of aircraft model. (NOTE: Configuration refers to modifications made to a basic aircraft model. For instance, A-4A, A-4B, TA-4F, etc., are all different configurations of the A-4 aircraft model.)

The directives are also grouped according to type under each configuration of aircraft model. The types of directives consist of Airframe Bulletins and Changes, Accessory Bulletins and Changes, etc. Among these types are Support Equipment Bulletins and Changes. As indicated, these support equipment directives are applicable to specific aircraft configuration(s). Such directives may involve the modification of the aircraft to accommodate certain test or other type support equipment, the modification of an item of support equipment for a particular configuration of aircraft model, or the modification of an item of special support equipment for a particular aircraft configuration.

A "General" Series is included in the last part of NAVAIR 00-500C. This section consists of those technical directives which are not limited to any specific aircraft but may be pertinent to equipment used in conjunction with all or, at least, several aircraft models. Like the preceding sections of this Index, the listings of directives in the General section are grouped according to type. Included are listings of Support Equipment Bulletins and Changes. As indicated previously, these directives are of a general nature and often involve improvement in performance, reliability, and/or safety of the specific item of equipment. For example, Support Equipment Change 1487 is listed in this section. This directive pertains to the NHS Hydraulic Power Supply Cart and involves modifications to improve reliability and decrease service maintenance on this item of equipment.

NOTE: Bulletins and Changes are discussed in more detail later in this chapter.

Microfilm Cartridge Cross Reference

The Microfilm Cartridge Cross Reference, NAVAIR 00-500M, is prepared in two parts:

Part I is a listing of NAVAIRSYSCOM Publications to the microfilm cartridge number. All of the publications listed have not been officially issued in microfilm cartridges. Part II is a listing of Maintenance Information Automated Retrieval System (MIARS) cartridge numbers and their latest film dates. Cartridge numbers not containing a film date are not available for issue. These cartridges will be available in the near future.

Updating the Index

As indicated by the previous discussions, the different Lists of the Naval Aeronautic Publications Index provide various cross-reference lists whereby technicians and mechanics can locate and identify available technical publications applicable to specific items of equipment. The Index has undergone many changes to improve this system of indexing technical publications. Although the Equipment Applicability List, NAVAIR 00-500A, has been a vital part of the Index for several years, it has recently undergone a major revision which is reflected in the previous discussion. The listing of each change to manual-type publications separately under different stock numbers is a recent change to Part C of the Numerical Index. Explanations of such changes are included in the introductory pages of the affected List. Therefore, when new issues of the lists are received, the introductory pages should be checked thoroughly for any changes that may have been incorporated.

The publications listed in the Index continually change. New equipment requires new publications. Old and obsolete equipment is retired and the applicable publications are canceled. Changes to equipment require additional publications and/or changes and revisions to existing publications. Therefore, some means must be provided to update the Naval Aeronautic Publications Index. To accomplish this, each List of the Index is updated at regular intervals by the issuance of a new List. In addition, some of the Lists are kept current by the periodic issuance of supplements between issues of the complete List. The methods used to update each List are discussed in the following paragraphs.

NOTE: The following information concerning the dates and intervals for the issuance of new Lists and supplements was current at the time of this writing. However, these dates and intervals have changed from time to time in the past. Therefore, the introductory pages of each new basic List and supplement should be checked for any changes of these dates and intervals.

The equipment Applicability List, NAVAIR 00-500A, is issued annually and supplemented bimonthly. It lists aircraft components, related equipment by model, type, and part number in alphabetical and numerical sequence with the applicable publication shown in the appropriate columns.

The Aircraft Application List, NAVAIR 00-500B, is issued annually with no supplements. It lists aeronautical manual publications with respect to their application to specific aircraft. It also lists technical manuals dealing with electronics, armament, instruments, powerplants, etc.

The Directives Application List, NAVAIR 00-500C, is issued annually with no supplements. It lists active NAVAIR letter-type technical directives with respect to their applicability to a specific aircraft, and a general category listing of directives that apply to all aircraft or ground support equipment.

The Microfilm Cartridge Cross Reference NAVAIR 00-500M is issued annually with bimonthly revisions and is prepared in two parts. Part I is a listing of NAVAIRSYSCOM publications to microfilm cartridge number. Part II is a listing of MIARS cartridge numbers and their latest film dates.

PUBLICATIONS NUMBERING SYSTEM

Code numbers are assigned to all publications in order that they may be identified, indexed, and filed. A knowledge of the numbering systems will enable the ASM to locate any desired information with a minimum of effort. A brief explanation of the coding of publications listed in the Index is presented in the following paragraphs.

Manuals

Code numbers assigned to manuals consist of a prefix and a series of three parts. All manual-type publications are listed in the Index with the prefix NA. This is the shortened form for NAVAIR and identifies those publications originated by the Naval Air Systems Command. However, the prefix NW appears on some of the older publications. This is the shortened form for NAVWEPS and indicates those publications originated by the Bureau of Naval Weapons before it was absorbed into the Naval Air Systems Command. When these publications are revised the prefix will be changed to NA.

The three parts which make up the remaining portions of the number indicate the following:

Part I is a two-digit number that indicates the general subject classification of the equipment covered by the publication. Table 5-1 lists the general subject categories and the appropriate two-digit numbers.

Part II of the publication code number consists of numbers and/or numbers and letters and indicates the specific class, group, type, or model and manufacturer of the equipment. The subject breakdowns of the 17 and 19 series are listed in table 5-2.

Part III consists of a number or numbers which designate a specific manual. For some manuals, this number designates a specific type of manual; however, for those pertaining to support equipment, this part is assigned in numerical sequence and has no reference to the type of manual.

Figure 5-2 illustrates the identification and decoding of a complete manual publication number.

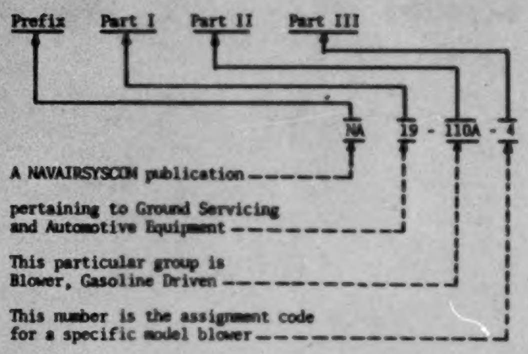
Letter Type Directives

There are two numbering systems used to identify letter type directives pertaining to support equipment. They are as follows:

1. Numbered in consecutive order according to specific application. For example, Support Equipment Change 590 is the 590th change that has been issued pertaining to

Table 5-2.—Subject breakdown of series 17 and 19 manual type publications

	17 Series - Machinery, Tools, and Test Equipment.
17-1	Shop and Warehouse Machinery, Tools and Test Equipment General.
17-5	Shop and Warehouse Machinery, Powered Tools and Equipment.
17-10	Shop and Warehouse Machinery, Powered Tools and Equipment.
17-15	Laboratory and Shop Test and Inspection Equipment.
17-20	Instrument Calibration Procedures.
17-25	Measurement System Operation Procedures.
17-30	Cross-Check Procedures.
17-35	Miscellaneous Calibration Publications.
17-600	Ground Support Maintenance Requirements Cards.
	19 Series - Ground Servicing and Automotive Equipment.
19-1	General.
19-5	Oxygen Equipment.
19-10	Airfield Lighting Equipment.
19-15	Platforms and Scaffolds.
19-20	Portable Shop Equipment.
19-25	Fire Trucks, Miscellaneous Trucks and Trailers.
19-30	Field Starters (Mobile).
19-35	Air Compressors (other than for Powerplants).
19-40	Tractors and Aircraft Towing.
19-45	Mobile Electric Power Plants.
19-50	Generators for Other Than Power Plants.
19-60	Portable Heaters and Coolers.
19-70	Aircraft Hydraulic Jacks.
19-75	Generator Skid or Trailer Mounted (Gas Nitrogen).
19-80	Motorized Material Handling Equipment.
19-105	Gas Turbine Compressors and/or Power Units and Enclosures.
19-110A	Blower, Gasoline Driven.
19-600	Ground Support Maintenance Requirements Cards.


Prefix
Part I
Part II
Part III
NA
19 - 110A - 4
A NAVAIRSYSCOM publication
pertaining to Ground Servicing and Automotive Equipment
This particular group is Blower, Gasoline Driven
This number is the assignment code for a specific model blower

226.2

Figure 5-2.—Identification and decoding of manual publication code number.

support equipment. The changes pertaining to all support equipment are grouped together and numbered in sequence. Bulletins are numbered in the same way; however, those pertaining to specific items of auxiliary power servicing equipment are numbered separately by each item of equipment.

2. Numbered in consecutive order according to subject matter. This method covers all Naval Air Systems Command Instructions and Notices. An example is NAVAIR Instruction 10340.1. The number 10340 indicates the general subject of the instruction, and the .1 indicates it is the first instruction issued by the Naval Air Systems Command on that particular subject. Notices carry the general subject number only, and do not carry a point number (i.e., .1).

NOTE: Instructions and Notices are not listed in the Naval Aeronautic Publications Index.

SECURITY OF CLASSIFIED PUBLICATIONS

The Department of the Navy Information Security Program Regulation, OPNAV Instruction 5510.1 (Series), issued by the Chief of Naval Operations, is the basic security directive relating to safeguarding classified information. Its provisions apply to all military and civilian personnel and all activities of the Naval Establishment.

The manual contains detailed instructions for classifying, marking, and handling classified information, and for access to an authorized disclosure of the information.

The ASM from time to time, has occasion to use classified publications relating to the performance of his work. Before he accepts such publications he must be cleared to the appropriate degree to handle this classified matter. It is then mandatory that he have a knowledge of and abide by the instructions in the Security Manual pertaining to handling classified material.

Publications listed in the Numerical Listing of the NAVSUP Publication 2002 are unclassified unless otherwise marked "1" (confidential) or "4" (secret) in the column headed "PS" (physical security). Classified publications listed in the Equipment Applicability List, NAVAIR 00-500A, are identified by the letter C (confidential) or the letter S (secret) in the column headed "SC" (security classification). Classified publications are identified in the same manner in the supplement to the respective Lists.

PROCUREMENT OF PUBLICATIONS

There are four main methods of procuring publications relating to the operation and maintenance of ground support equipment.

The first method is initial outfitting. The Naval Air Technical Service Facility (NATSF) automatically provides the prospective commanding officer of a newly commissioned or reactivated ship, station, or activity an outfitting of general aeronatuic publications.

Specific publications obtained under Aeronautic Technical Publications Outfitting Allowance constitutes another prime source of publications. Initial distribution is provided by NATSF to a newly commissioned or reactivated activity. When support activities change mission of aircraft, support equipment requirements often change. Such changes may require a different set of publications. Upon such a change, an Aeronautic Technical Publications Outfitting Allowance, applicable to the model designation of the aircraft and equipment involved, may be obtained by letter request from the commanding officer to NATSF.

The third source of publications is through inclusion in automatic distribution lists. The NATSF normally provides for the issue of certain future issues of new and revised publications directly to affected activities. Activities desiring to receive future issues of new and revised publications must submit a "Mailing List Request for Aeronautic Publications" (currently Form NAVAIR 5605/3) to the Commanding Officer, NATSF. Personnel of the support equipment work center desiring to receive particular issues, reissues, and revisions of publications should make their requirements known to the technical library so that they may be included on the next submission of Form 5605/3.

The fourth method of procuring publications is by ordering individual publications direct. Manual-type publications must be ordered on a Single Line Item Requisitioning System Document (DD Form 1348 or DD Form 1348m). Technical letter-type publications must be ordered on DD Form 1149. The use of any of these three forms will not result in being placed on the distribution list to receive future issues or revisions of publications ordered.

MANUAL-TYPE PUBLICATIONS

As shown in table 5-1, manuals are published in a number of different subject categories. Those of special interest to the ASM are the General Manuals (00 series) and Support Equipment Manuals (17 and 19 series). Certain manuals in other series may be used occasionally, but those listed here are of special importance to the Aviation Support Equipment Technician.

General Manuals (00 Series)

As indicated by the title, this series of manuals includes information of interest to all naval aviation personnel. Included are three parts of the Naval Aeronautic Publications Index (00-500A, 00-500B, 00-500C described previously), NAVAIR Outfitting Lists and Allowance Lists, and Aviation Training Literature.

OUTFITTING LISTS AND ALLOWANCE LISTS (00-35Q SERIES).–Aircraft maintenance support and repair parts for aircraft maintenance repair and listed in NAVAIR Initial Outfitting Lists and Allowance Lists. The equipment and parts listed in these publications are made available to aircraft operating and maintenance activities in accordance with assigned operational and maintenance responsibilities through appropriate applications of Allowance Lists and Outfitting Lists.

The Aeronautical Allowance Lists Program is designed to cover the various types of aircraft support equipment and repair parts considered to be required by maintenance activities.

Repair parts, nuts, bolts, etc. are included in the publications identified as Initial Outfitting Lists. Maintenance support equipment items such as test stands, aircraft jacks, lubricating guns, wrenches, drills, compass testers, and voltmeters are included in publications identified as Allowance Lists.

These Lists are identified by Sections. Certain sections such as H and K are issued as individual publications. Others such as B, R, and Z appear as a series of publications, each of which is applicable to a specific model of equipment, model of aircraft, or type of activity.

The ASM should be especially familiar with the following sections:

Section G Allowance List, General Support Equipment. This section lists general handtools, consumable support equipment, and installed shop equipment.

Section K, Allowance List for Naval Aeronautic Publications and Forms.

Section Z Initial Outfitting Lists. These list peculiar repair parts for mobile electric powerplants, precision measuring equipment, and peculiar and common ground support equipment.

Allowance Lists and Outfitting Lists, in conjunction with the IMRLs (explained later in this chapter), consist of listings of the equipment and material (both expendable and accountable) necessary to place and maintain activities of the aeronautical organization in a material readiness condition. Allowances contained in these Lists are based on known or estimated requirements and on available usage data.

All Allowance List and Outfitting List code numbers include NA as a prefix (discussed previously) followed with 00-35Q plus the section identification letter and a dash number to identify a particular section or series. For example, a section Z Initial Outfitting List which contains a listing of spare parts for hydraulic test stands is numbered NA 00-35 QZ-39.

A program closely related to the Allowance Lists and Outfitting Lists is the Aircraft Maintenance Material Readiness List (AMMRL). This program provides for the development of data and documentation needed to determine and establish firm support equipment requirements and inventory control of aircraft maintenance support equipment. Within the AMMRL there are material readiness lists, which are discussed in the following paragraphs.

The Application Data Material Readiness List (ADMRL) is used to specify the requirements for each item of aircraft maintenance support equipment against each level of maintenance and selected ranges of each aircraft, engine, propeller, and system for which each item is needed. The initial ADMRL is established by NAVAIRSYSCOM. Through the use of data processing machines this data is used to develop Individual Material Readiness Lists.

The Individual Material Readiness List (IMRL) specifies items and quantities of ground support equipment required for material readiness of the aircraft maintenance activity to which the list applies. The list applies to an activity by name. The Naval Air Systems Command Representative is responsible for the preparation of the IMRL for each activity in his cognizant area. It is prepared by extracting from the ADMRL those applicable portions which pertain to the specific aircraft and maintenance material assignments of the activity for which the list is developed.

The IMRL should be reviewed annually and updated by each activity to support current and anticipated changes in ground support equipment requirements. Because the IMRL is continually reviewed and updated and approved by the cognizant command, it is the firm mandatory material readiness list of the activity to which the list applies.

TRAINING LITERATURE (00-80 SERIES).—This series of publications is issued by authority of the Deputy Chief Naval Operations (Air). Included are various Air Safety Pamphlets and General Aviation Training Publications. For example, NA 00-80T-96, Aircraft Support Equipment, General Handling and Safety Manual, is one of the training manuals in this series.

Support Equipment Manuals (17 and 19 Series)

The 17 and 19 series of aeronautic technical manuals cover most types of support equipment. The manufacturer of each item of support equipment is required to furnish adequate instructions for operating the equipment and maintaining it throughout its service life. These manuals are prepared by the manufacturer and are issued under the authority of the Naval Air Systems Command. They are then official Navy publications.

Support equipment manuals contain descriptive data; detailed instructions for operation, servicing, inspection, maintenance, repair, and overhaul; and illustrated parts lists. All available support equipment manuals are listed in the appropriate parts of the Naval Aeronautic Publications Index. NAVAIR 00-500A lists available manuals in reference to the model, type, and/or part number of the equipment. All available support equipment manuals are listed in numerical order (by the publication number) in NAVSUP 2002. In addition, support equipment manuals are listed (by publication number only) in NAVAIR 00-500B in respect to their application to each model and configuration of aircraft.

If an item of support equipment is relatively simple, all the necessary instructions may be contained in a single manual. An example is NA 19-1-60, Operation, Service, and Overhaul Instructions with Illustrated Parts Breakdown for the Aircraft Universal Towbar Assembly. More complex equipment may require two or more manuals. For example, one manual may contain operation, service, and repair instructions, while the parts breakdown is contained in a separate manual.

Regardless of the number of manuals used to contain these instructions, the terms Operation, Service, and Repair (or Overhaul) are usually used in the title of these instructions. However, some of the newer models of equipment are provided with manuals for different levels of maintenance. In this case, the manuals are titled Maintenance Instructions, Organizational Level; Maintenance Instructions, Intermediate Level; and, if required, Maintenance Instructions, Depot Level.

OPERATION AND SERVICE INSTRUCTIONS.–Although sometimes issued as separate manuals, Operation and Service Instructions for each item of support equipment are usually combined into one manual, and, as previously stated, are often combined with other instructions and the parts breakdown. Operation and Service Instructions include information necessary for organizational level maintenance.

Operation and Service Instructions Manuals are divided into sections. The manuals vary as to content and number of sections. The following is a description of the sections of a typical manual.

The first section usually contains an introduction and description of the equipment. This includes a general description and purpose of the item of equipment and brief descriptions of the major components. This section also usually contains a table of specifications. These specifications include such information as the weight and overall dimensions of the equipment; capacities of the fuel, oil, and cooling systems; the manufacturer, model, and type; and leading particulars of the engine, fuel system components, electrical systems components, transmissions, etc.

In some manuals section II contains a list of special tools required for the operation and service of the equipment.

The next section gives information pertaining to the preparation of the unit for use. Instructions necessary for unpacking and assembling the unit are covered in this section. This section also includes any adjustments and inspections that must be made and any safety precautions that must be observed before the unit is operated. Some manufacturers include in this section information concerning the preparation of the unit for storage and shipment.

The next section gives complete and detailed operating procedures for the equipment. Such information as the principles of operation, the purpose and use of the operating controls, and the purpose and use of the indicating instruments are included in this section. Normal operating pressures and temperatures are also given. Safety precautions in the form of WARNINGS and CAUTIONS are inserted in the appropriate parts of the text. These same methods of presenting safety precautions are used in all support equipment instructions manuals.

The service instructions are contained in the next section. These instructions pertain to periodic inspections, maintenance, and lubrication. Charts or tables are usually used to indicate the inspection interval of systems and components. (Periodic inspections of most support equipment are performed in accordance with Maintenance Requirements Cards which are used in conjunction with the information contained in this section.) The specifications for oil, fuel, lubricants, etc., are included in this section. Diagrams, showing the places to be lubricated, are also included. In some manuals, troubleshooting charts are included in this section. Other manuals contain an additional section for these charts.

The Operation and Service Instructions, as well as the other parts of support equipment manuals, usually contain illustrations to clarify the text. The illustrations provided in support equipment manuals are similar to those presented in this training manual; a wide variety of graphic presentations is utilized. These include pictorial drawings (isometric drawings and reproductions of photographs), orthographic drawings, and schematic and block diagrams. Combinations of these drawings and diagrams are utilized in some illustrations.

NOTE: For detailed information concerning different types of drawings and diagrams, including the definitions of terms used in conjunction with these graphic presentations, refer to *Blueprint Reading and Sketching,* NavPers 10077 (Series) which also illustrates many of the different symbols used on diagrams.

REPAIR OR OVERHAUL INSTRUCTIONS.–Information pertaining to intermediate level maintenance of support equipment is usually issued as Repair or Overhaul Instructions. In some manuals this information is titled Maintenance Instructions and covers the repair and/or overhaul of the equipment.

The title of this type manual or section of the manual, depends upon the type of maintenance that must be performed on the equipment. Some equipment simply requires repair and replacement of defective parts. Repair, as it applies to maintenance of aeronautical equipment, is the restoration of an item of equipment to an acceptable operating condition without complete disassembly and inspection. The maintenance information required for this type equipment is usually issued as Repair Instructions.

Some items of support equipment must be overhauled at regular intervals. Overhaul is the disassembly of an item of equipment as required to permit inspection of every component part. Component parts which, upon inspection, will not meet requirements as set forth in applicable specifications are restored or replaced by new parts so that after reassembly and test, the equipment will meet the requirements set forth in the applicable specifications. Maintenance information of this type is generally issued as Overhaul Instructions. The overhaul intervals (number of miles, number of starts, hours of operation, months of operation, etc.) are specified in the Overhaul Instructions.

If the Repair or Overhaul Instructions are published as a separate manual, the first section is a brief introduction. This includes the purpose and leading particulars of the item of equipment. The remainder of the manual contains complete repair or overhual instructions and test procedures. If combined with the Operation and Service Instructions, the Repair or Overhaul Instructions are arranged in a section, or sections, following the service instructions.

ILLUSTRATED PARTS BREAKDOWN.–The purpose of the Illustrated Parts Breakdown (IPB) is to assist supply and maintenance personnel in the identification, requisitioning, and issuing of parts for the applicable item of support equipment.

The IPB for some complex items of support equipment is issued as a separate manual and has its own identification number. The IPB for most items of support equipment is combined with one or more sections of the instructions manuals and is the last section or sections of the manual. An example of the title of a combined manual is Operation and Service Instructions with Illustrated Parts Breakdown.

Although the IPB appears in some manuals as one section, it is usually divided into three sections or parts–Introduction, Group Assembly Parts List, and Numerical Index. In addition to these three parts, a Table of Contents is provided. If the IPB is a separate manual, the Table of Contents is contained in the first few pages of the manual. If the IPB is combined with instructions manuals, a combined Table of Contents appears in the first few pages of the combined manual. In either case, the Table of Contents contains a List of Illustrations which plays an important role in locating parts in the IPB.

The Introduction contains detailed instructions for the use of the IPB. All the information in this section should be read prior to using the remaining sections. The information in the Introduction will aid the ASM in locating the necessary part or parts quickly and easily.

The next section, Group Assembly Parts List, lists and illustrates the assemblies and parts of the equipment. As mentioned previously, exploded views are usually used to illustrate these assemblies and parts. The parts lists are used in conjunction with the illustrations. Index numbers in the parts lists correspond to those on the illustrations. This section and the List of Illustrations are used to locate and identify a part when the part number is unknown. The steps involved in this process are presented in figure 5-3.

The last section, the Numerical Index, contains an alphanumerical listing of all the parts in the IPB. In addition to the part numbers, the Numerical Index contains such information as national stock number data, figure and index numbers, source code data, and repair code.

The Numerical Index is used to find the illustration and nomenclature of a part if the part number is known. Figure 5-4 illustrates the steps involved in this process.

Technical Information File of Ground Support Equipment

The Military Standardization Handbook, Technical Information File of Ground Support Equipment. MIL-HDBK-300B, provides a consolidated source of descriptive information about individual items of ground support equipment used by the Navy, Air Force, and Army. It consists of several volumes and provides descriptive information such as:

1. Official nomenclature of the item.
2. Manufacturer and model/type number.
3. Functional classification.
4. National stock number.
5. A photograph or drawing of the item.
6. Functional description (purpose).
7. Its relation to other equipment.
8. Electromechanical/mechanical description (technical details).
9. Reference data and literature available about the item.
10. Shipping data (size, weight, etc.).

Updating Manuals

Modern technology is a constantly changing thing. What is considered to be the "latest" word today may be modified, totally revised, or otherwise made obsolete tomorrow. This is not always a planned or intended condition, but it must be accepted and dealt with.

These changing conditions apply to aeronautic technical publications. They require that prompt action be afforded to change and revise all material which is related to the technical information and data used by maintenance and operational personnel.

The degree of urgency of updating publications depends upon the type of information involved and the frequency of reference to the affected publications. In any event, technical data change and revision material should not be allowed to accumulate at any point.

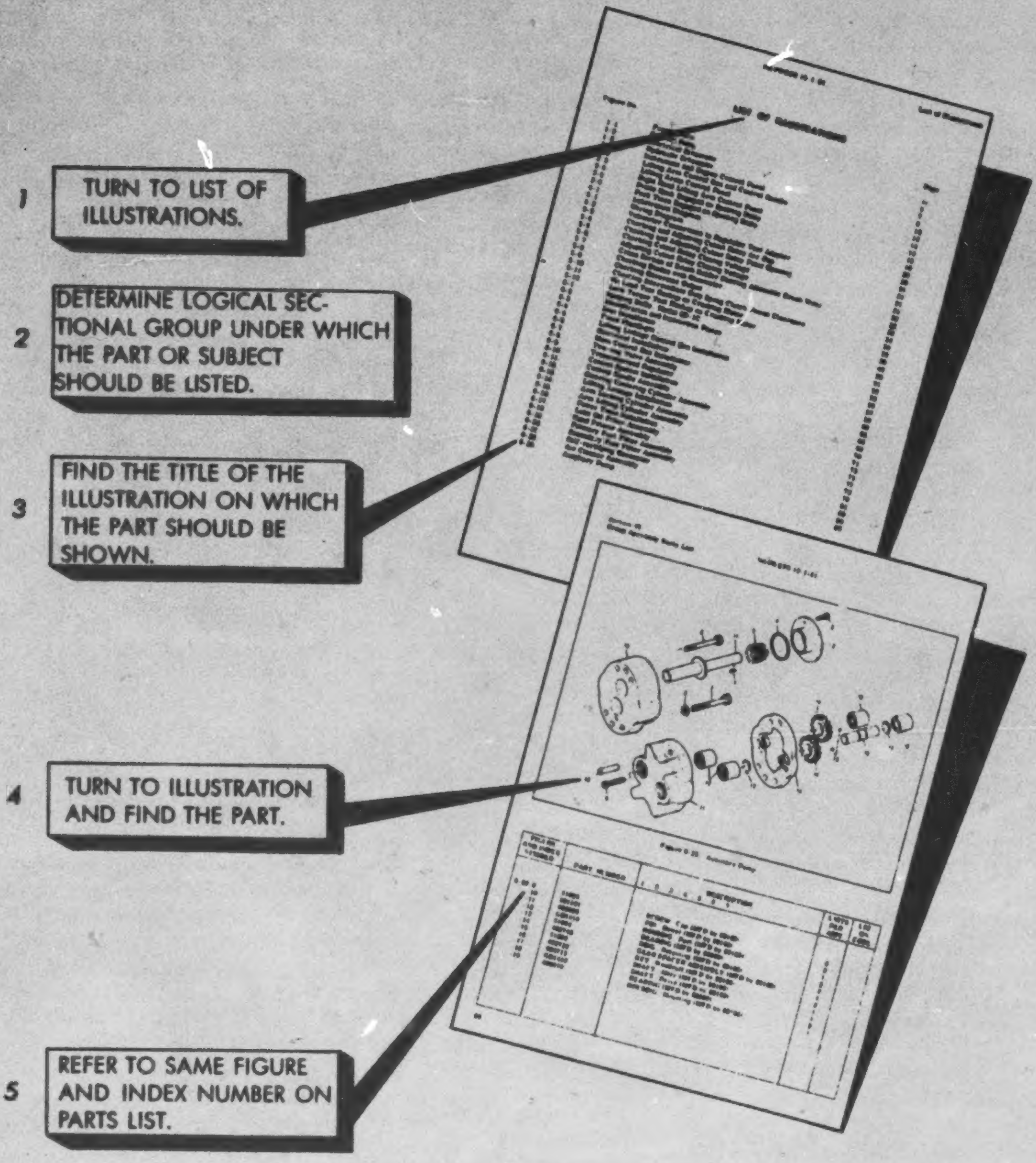
Copies of these changes and revisions, received through the proper submission of NAVAIR Form 5605/3, are first delivered to the technical library. Personnel of the library make the necessary changes to the affected publications filed in the library. However, the changes affecting the publications held by the production divisions are routed to the appropriate work center. Personnel of the work center are then required to incorporate the changes into their copies of the affected publications.

The changes or revisions are prepared by the manufacturer of the specific equipment and are issued under the authority of the Naval Air Systems Command. The changes or revisions may direct write-in changes, provide replacement/additional pages, and/or provide information affecting various parts of the manual, in which case the information is prepared as supplemental data.

When incorporating changes, the instructions provided on the front page of the change should be followed exactly. Write in material should be entered neatly and legibly using indelible ink. Text material to be deleted should have a single line ruled neatly through every line of type.

Supplemental data is supplied on pages to be filed next to the affected pages in the manual. Supplementary pages are inserted in the manual in page number order and are identified by a letter added to the page number. For example, if a supplementary page is issued bearing the number 2-16A, it is placed between pages 2-16 and 2-17. The supplementary information may be applicable to either or both of these pages.

Replacement pages are designed to replace pages already in the basic publication. They are



1 TURN TO LIST OF ILLUSTRATIONS.

2 DETERMINE LOGICAL SECTIONAL GROUP UNDER WHICH THE PART OR SUBJECT SHOULD BE LISTED.

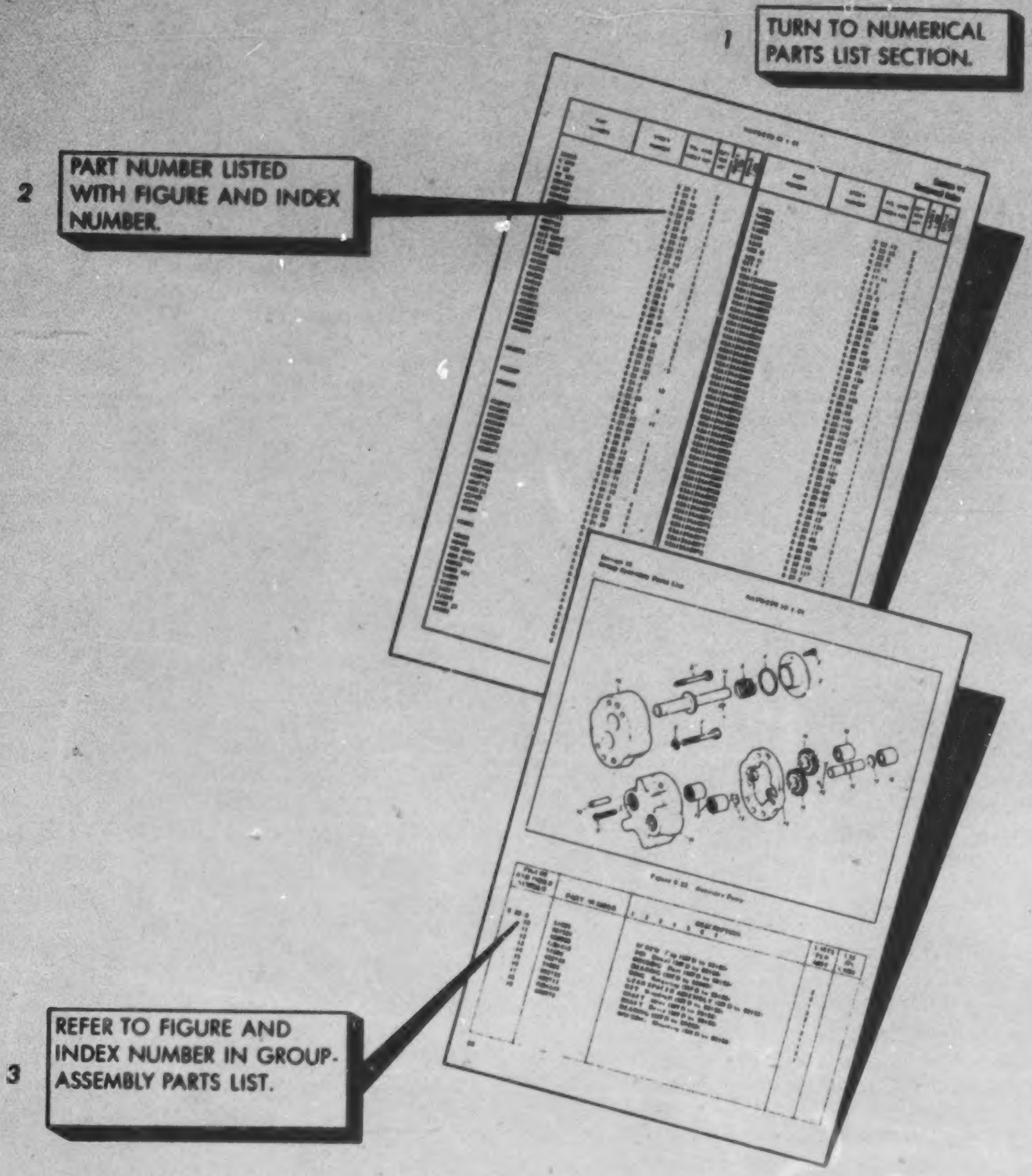
3 FIND THE TITLE OF THE ILLUSTRATION ON WHICH THE PART SHOULD BE SHOWN.

4 TURN TO ILLUSTRATION AND FIND THE PART.

5 REFER TO SAME FIGURE AND INDEX NUMBER ON PARTS LIST.

225.8

Figure 5-3.—Use of the IPB when the part number is unknown.



1 TURN TO NUMERICAL PARTS LIST SECTION.

2 PART NUMBER LISTED WITH FIGURE AND INDEX NUMBER.

3 REFER TO FIGURE AND INDEX NUMBER IN GROUP-ASSEMBLY PARTS LIST.

225.8

Figure 5-4.—Use of the IPB when the part number is known.

numbered in exactly the same way as the pages they replace. The date of the change is shown on the bottom of the page in the corner opposite the page number. Prior to incorporating replacement pages they should be counted and the number noted. When the task is finished, the removed pages should be counted to make sure that the same number were removed as were put in. Also, the bottom of each removed page should be checked for dates to make sure no new replacement pages were inadvertently missed.

On the back of each change notice cover page is a cumulative list of all changed/revised pages issued and the date of issue, since the basic date of the manual. Checking the listed pages and dates against the corresponding pages of the manual, which are also dated, provides one method of determining currentness and completeness of the manual. This page becomes the cover page of the revised manual.

In addition to the normal technical manual change and revision system described above, a Rapid Action Change (RAC) system has been developed recently to improve the timely issuance of urgently required information. Under this system, information affecting flight safety, hazards to personnel, or grounding of aircraft is disseminated via naval message and immediately incorporated in the affected manual. A manual change page follow-up is then required within 15 days of the release of the message. As indicated by the type of information disseminated in this manner, this system pertains primarily to aircraft technical manuals. However, support equipment can indirectly affect flight safety and grounding of aircraft and can directly cause hazards to personnel; therefore, the RAC system is also applicable to support equipment manuals. In addition to the message type of change, information of a less urgent nature is disseminated by RAC change pages that must be printed within 30 days after problem resolution and is generally limited to 12 pages or less.

It should be emphasized that the RAC system does not affect the normal change and revision requirements. The RAC system merely supplements the existing change system to provide for rapid issue of urgently required data.

LETTER-TYPE DIRECTIVES

There are two broad categories of letter type directives. One category pertains to information of a technical nature and includes Bulletins and Changes. This category is referred to as Technical Directives. The other category pertains to policy and administration procedures. Instructions and Notices are used to disseminate this type of information. These different forms of letter-type directives are discussed in the following paragraphs.

Technical Directives

The Technical Directive System has been established for the control and issue of all technical directives. This system standardizes the method of issuance for such directives and is the authorized means for directing the accomplishment and recording of modifications and onetime inspections of ground support equipment as well as aircraft and other aeronautical equipment. The Technical Directive System is an important element in the programs designed to maintain equipment in a safe and current state of operational and material readiness.

This system provides for two types of technical directives. The types are determined by the method of dissemination. The two types are Formal (letter-type) and Interim (message-type). In general terms, they are both considered as letter-type publications. Such directives contain instructions or information of a technical nature which cannot be disseminated by revisions or changes to technical manuals. However, the accomplishment of a technical directive often necessitates a change or revision to the applicable technical manual. Technical directives are issued in the form of Changes, or in the case of special circumstances, by Interim Changes or Interim Bulletins.

A formal technical directive is issued as a Change, or as an amendment or revision thereto, and is disseminated by letter. Formal directives are used to direct the accomplishment and recording of modifications to support equipment, as well as aircraft and related equipment. An interim technical directive is issued as a Change or a Bulletin, or as an amendment or revision thereto, and, in order to ensure prompt delivery to the concerned activities, it is disseminated by message. The interim technical directive is reserved for those instances when it is necessary to correct a safety or operational condition whenever it is considered too important to risk waiting for the issuance of a formal directive.

Each Interim Change is superseded by a Formal Change directive which will have the same number as the interim directive. Interim Bulletins are not superseded by Formal Bulletins as was previously the case. NAVSUP Publication 2002, will still have many Interim Bulletins listed until they are eventually phased out.

A Change is a document containing instructions and information which directs the accomplishment and recording of a material change, a repositioning, a modification, or an alteration in the characteristics of the equipment to which it applies. A change is issued to direct that parts be added, removed, or changed from the existing configuration or that parts or material be altered, relocated, or repositioned.

A Change may be issued in parts to accomplish distinct parts of a total directed action or to accomplish action on different configurations of affected equipment.

A Bulletin is an interim document comprised of instructions and information which directs an initial inspection to determine whether a given condition exists. It specifies what action is to be taken if a given condition is found or not found.

Sometimes it is found that a Change or Bulletin is not the complete answer to a problem, and it is determined necessary to amend or revise an outstanding directive. An Amendment is a document comprised of information which clarifies, corrects, adds to, deletes from, makes minor changes in requirements to, or cancels an existing directive. It is only a supplement to the existing directive and not a complete directive in itself. A maximum of three Amendments may be applied to any technical directive, each remaining in effect until rescinded or superseded by a Revision. A requirement for further amendment action necessitates the issuance of a Revision.

A Revision is a completely new edition of an existing technical directive. It supersedes the original directive and all existing Amendments.

Interim Bulletins are self-rescinding with rescission dates of 30 June and 31 December, whichever is appropriate for the case at hand. Rescission is the process by which a technical directive is removed from active files after all requirements have been incorporated and recorded. Rescinding dates are also projected for formal changes. Final rescission action of all technical directives is directed in NAVSUP Publication 2002. All activities maintaining files of technical directives should retain all technical directives until they are deleted from NAVSUP Publication 2002.

Changes and Bulletins are issued by technical personnel of the Naval Air Systems Command and are based on Contractor Service Bulletins, on reports from various Data Services, or letters of recommendation or proposed modifications from field service activities. They are automatically distributed to all activities concerned through inclusion on the Mailing List Request for Aeronautic Publications, NAVAIR 5606/3.

Changes and Interim Changes are assigned numbers in a numerical sequence by the Technical Directives Control Center, located at the Naval Air Technical Services Facility (NATSF), Philadelphia, Pa. A Formal Change which supersedes an Interim Change will have the same number as the Interim Change. Interim Bulletins are numbered similarly in another number series.

The title of a Change or Bulletin for support equipment is made up of three parts. Part one is the term "Support Equipment," part two, the word or words "Change," "Interim Change," or "Interim Bulletin;" and part three, the sequential number. When applicable, the words "Rev. A," "Amendment 1," etc., follow the basic directive.

Changes are classified by various "action" categories. Bulletins may also be assigned an action classification, but it is not mandatory. The assigned action category serves as a priority for compliance with the various directives.

The category "Immediate Action" is assigned to directives which are issued to correct safety conditions, the incorrected existence of which would probably result in fatal or serious injury to personnel, or extensive damage or destruction of property. Immediate Action directives involve the discontinued use of the equipment in the operational employment under which the adverse safety condition exists, until the directive has been complied with. If the use of the equipment will not involve the use of the affected component or system in either normal or emergency situations, compliance may be deferred, but should be accomplished no later than 120 days from the date of issue. Immediate Action directives are identified by a border of black X's on the cover page, broken at the top center of the page by the words "IMMEDIATE ACTION," printed in black.

The category "Urgent Action" is assigned to directives which are used to correct safety conditions which, if uncorrected, could result in personnel injury or property damage. This category of directive is identified by the words "URGENT ACTION" printed in black ink at the top of the first page and a border of black diagonals around the cover page.

The compliance requirements for Urgent Action directives specify that the incorporation of the instructions must be accomplished not later than the next regularly scheduled rework or overhaul or, for equipment not reworked or overhauled on a regularly scheduled basis, not later than 18 months after the date of issuance.

Routine Action directives are issued where there are reliability, capability, or maintainability deficiencies which could, if uncorrected, become a hazard through prolonged usage or have an adverse effect on the operational life or general service utilization of equipment. The compliance requirement specifies the incorporation of the instructions not later than the next regularly scheduled overhaul or rework, or for equipment not reworked or overhauled on a scheduled basis, not later than 18 months after issuance of the directive. If accomplishment of the work requires depot level maintenance capability, the compliance may be deferred if it will seriously interfere with operational commitments or schedules. Routine Action directives are identified by the words "ROUTINE ACTION" printed in black capital letters at the top center of the cover page and no border symbols are used. Table 5-3 illustrates the technical directives priority system just described.

Record Purpose category is assigned to a technical directive when a modification has been completely incorporated by the contractor before acceptance by the Navy. This category of technical directive merely documents the action for configuration management purposes. Consequently, compliance information is not applicable. They are identified by the words "RECORD PURPOSES" printed in black capital letters at the top center of the cover page.

Instructions and Notices

Instructions and Notices are directives containing information and instructions concerning policy, administration, and air operations. They are issued by all systems commands, bureaus, ships, stations, and operating activities. Those issued by the Naval Air Systems Command are known as NAVAIR Instructions and Notices.

Instructions are directives of a continuing nature and are effective until canceled or superseded by a later directive.

Notices are directives of a one-time nature of directives which are applicable for a brief period of time. Each Notice contains a provision for its own cancellation.

Instructions are numbered in consecutive order according to the subject covered in the Instruction. Notices are not assigned consecutive numbers because of their one-time nature or brief duration. For this reason, the date must always be used when referring to a Notice. Those Instructions and Notices pertaining to aviation maintenance may be addressed to "All Ships, Stations, and Units concerned with Naval Aircraft," or to certain activities only. Each activity maintains a file of all pertinent Instructions and Notices still in effect.

MISCELLANEOUS AVIATION PUBLICATIONS

Several unofficial publications of general interest to aviation personnel are available in

Table 5-3.–Technical directives priority system

Action classification	Type directive	Situation	Time limits for compliance
Immediate	Interim or Formal	Use of the equipment INVOLVES use of the affected component or system in normal or emergency operation.	Prior to further use of the affected equipment.
		Use of the equipment DOES NOT INVOLVE use of the affected component or system in either normal or emergency operation.	Not later than 120 days after issuance.
Urgent	Interim	Use of the equipment INVOLVES use of the affected components or system in normal or emergency operation.	Not later than next regularly schedule rework or overhaul.
		Use of the equipment DOES NOT INVOLVE use of the affected component or system in either normal or emergency operation.	Same as above.
	Formal	Any	Within 18 months of the date of issue.
Routine	Formal	Any	Within 18 months of the date of issue.

most operating activities. These should be read regularly by all maintenance personnel.

Naval Aviation News

The Naval Aviation News, NAVAIR 00-75R-3, is published monthly by the Chief of Naval Operations and the Naval Air Systems Command. Its purpose is to disseminate data on aviation training and operations, aviation support equipment, space technology, missile, rocket, and other aviation ordnance developments, aeronautical safety, aircraft design, powerplants, aircraft recognition, technical maintenance, and overhaul procedures.

This publication is essentially a news magazine. It enables readers to keep abreast of the latest unclassified developments in every facet of naval aviation. In addition; the coverage of fleet operations and the human interest articles on the noteworthy feats and accomplishments of individuals, both officer and enlisted, make the Naval Aviation News an entertaining as well as an informational periodical.

Approach

Approach (NAVAIR 00-75-510), The Naval Aviation Safety Review, is published monthly by the U.S. Naval Aviation Safety Center and is distributed to all naval aeronautic organizations on the basis of 1 copy for every 10 persons. It presents the most accurate information currently available on the subject of aviation accident prevention.

A large number of aviation accidents are maintenance-induced; that is, they occur during preparation for, performance of, and securing from maintenance or as a result of sloppy or improper maintenance. Some aviation accidents result, either directly or indirectly, from careless use or improper maintenance of support equipment. Therefore, articles concerning aviation support equipment frequently appear in this magazine. For example, a recent article recommended that tires with military tread be used on support vehicles to decrease FOD (foreign object damage) to aircraft. In addition, many hints on general maintenance are issued in the Approach. Although these are primarily for aircraft maintenance personnel, they may also apply to the maintenance of support equipment. For example, a recent issue discussed the care of bearings, and another the use and care of torque wrenches.

The Approach magazine reports the results of accident investigations; and for those accidents that are maintenance-induced, describes what was done wrong and how it should have been done; suggests corrective measures to prevent future accidents resulting from these causes; and when appropriate, cites aeronautic technical publications which provide authority for changes in techniques or material to improve the maintenance product.

In short, the maintenance man who reads and heeds the messages in Approach is the man who benefits from other mechanics' experiences. Put Approach on your required reading list and look for it every month.

Crossfeed

Crossfeeds are "Official Use Only" publications issued by the Naval Safety Center. Each Crossfeed is in the form of a letter to the squadron aviation safety officer.

Due to the designation "Official Use Only," the Crossfeeds are not available for general distribution throughout an activity. The restriction to "Official Use Only" derives from OPNAV Instruction P3750.6(Series) which states in part "...distribution of AARs (Aircraft Accident Reports), incidents, and ground accident reports, MORs (Medical Officer's Reports), reports of special investigations of aircraft mishaps, or extracts therefrom, will be limited strictly to commanders and other authorities named..." Crossfeeds often contain such material extracted from AARs and from reports of special investigations.

Crossfeeds are prepared according to subject matter. For instance, those about which the Aviation Support Equipment Technician is most concerned are the Maintenance Crossfeeds and General Crossfeeds. From time to time these contain information of critical importance to the ASM in the performance of his duties.

The unit's aviation safety officer will generally pass on Crossfeed information to those with an obvious need to know and will follow up to see that it is used. However, each applicable Crossfeed should be checked for pertinent information by the ASM. It must be kept in mind that the average ASM will see only an occasional Crossfeed unless he goes out of his way to look for them. For those who understand the need for special handling of the information contained in Crossfeed and are interested enough in the information and their jobs to ask for it, these publications can provide a wealth of useful and timely information.

MECH

MECH is published quarterly by the U.S. Naval Safety Center and is distributed to naval aeronautical organizations on the basis of 1 copy per 10 persons. It presents the most accurate information available on maintenance-caused mishap prevention and general aviation ground safety. Contents are informational and should not be considered as regulations, orders, or directives.

The MECH's motto is "Our product is safety, our process is education, and our profit is measured in the preservation of lives and equipment and increased mission readiness."

MIARS

The Maintenance Information Automated Retrieval System, hereafter referred to as MIARS is designed to provide a projected display of maintenance manuals which are contained on 16mm microfilm cartridges.

To you, the technician who maintains GSE and on whom its safety depends, the delay between the time a technical manual change is issued and the time that change is translated into a repair is DANGER TIME in which naval personnel and equipment are exposed to possible injury or destruction. Any method that shortens or eliminates this DANGER TIME is a way to increase the safety potential.

MIARS is a program implemented by the Naval Air Systems Command which provides the aviation maintenance man with required technical information in a more efficient way than before. This new system means fast access to up-to-date, accurate, technical information, and you no longer have to lug around heavy paper manuals to your working area. All you handle is a 4-inch square cartridge in which the roll of microfilm is encased. The reader-printer (figure 5-5), on which the microfilm page can be displayed is near your work site, with its automatic retrieval system ready to use and its printer capable of reproducing only those pages required at the work site.

MIARS replaces bulky manuals with one cartridge weighing approximately 7-ounces. It contains approximately 2700 pages of information which would weigh 24 pounds in paper form. The much smaller size of microfilm makes shipment faster and storage easier, saving approximately 40% of the storage space taken up by paper manuals. Because MIARS provides for quick processing of manual changes and complete revised cartridges are issued rather than individual page changes, the tedious and inefficient job of inserting changes and pages into manuals is eliminated.

In addition to cartridges of microfilm, MIARS features two basic types of hardware equipment: AR-150A reader-printer (fig. 5-5) and the smaller AR-151A (fig. 5-6) portable readers. The reader-printers have a keyboard system for finding microfilm pages and a printer which can make up to seven copies of a microfilm frame. The portable readers are basic projectors that magnify and display microfilm information.

227.97

Figure 5-5.—AR-150A Reader-printer.

MICROFILM INDEX.–The Naval Aeronautics Microfilm Index, NAVAIR 00-500M, cross-references the manual number to cartridge filming date. The newest version of NAVAIR 00-500M is an index crossed-referenced by manual number, cartridge number, and equipment application. Manuals normally used together (i.e., MIM and IPB) will be in the same cartridge by level of maintenance and the digit of the Work Unit code. Refer to table 5-4 for example of using the NAVAIR 00-500M. Cartridges numbers starting with SE and numbers 1 thru 9 identify publications that are applicable to support equipment Work Unit Codes. The level of maintenance and reference library is identified by the numbers to the right of the decimal point, such as 1-299 Organizational, 300-599 Intermediate, 600-899 Depot.

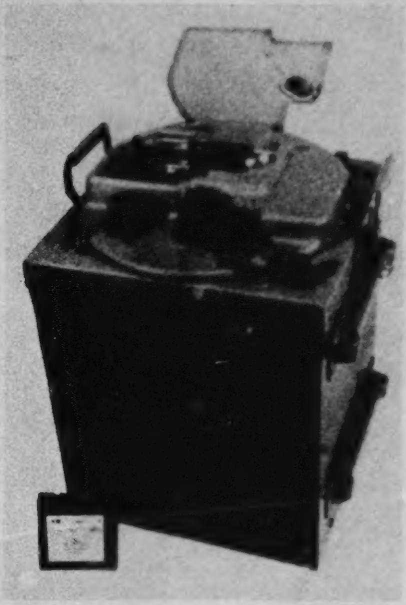


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Figure 5-6.—AR-151A Portable Reader.

DRAWINGS

At the beginning of World War II, the systems installed in aviation ground support equipment were not very complex. With a little study and some experience, the maintenance technician could become quite familiar with all the equipment used to support his unit. The equipments were not only comparatively simple, but similar in operation, and constructed in a manner which allowed ease of inspection and repair. It was possible to service, maintain, and repair this equipment with perhaps only an occasional reference to a manual or a schematic.

Presently, however, this practice is no longer possible. Even a mere listing of the systems installed in some of the more modern ground support equipment, such as a mobile electric power plant, would be quite lengthy. It is impossible for any one person to be thoroughly familiar with all of the various types of equipment in present use; but with a good general background of mechanical/electrical principles, a little study will enable the ASM to rapidly familiarize himself with any specific equipment.

The purpose of this chapter is to discuss some of the sources of information available, how to use these references, and how to locate details on items of information the ASM needs in the performance of his duties.

DRAWINGS AND DIAGRAMS

Nearly all technical manuals make extensive use of drawings and diagrams. The technician uses these figures in nearly every phase of his work—the location and identification of units and components, troubleshooting, signal and/or circuit tracing, installation, calibration and adjustment, testing, operation, and evaluation. He also uses these figures in the study of operating principles of circuits and equipments.

No one particular type of illustration is suitable for all applications; therefore, many different types are required. Several of the different types are discussed in the following paragraphs. Each type has its own advantages and disadvantages.

Illustrations

Illustrations are commonly used to present visually the idea of a text. To this end, illustrations are used in many forms. A few of these are the photograph, line drawing, shaded sketch, cutaway view, blueprint, etc. Some of

Table 5-4.—Cartridge numbering system

SE2 . 1

SUPPORT EQUIPMENT HANDLING EQUIPMENT — SE2

ORGANIZATIONAL FIRST CARTRIDGE — 1

the more common illustrations are discussed briefly in this chapter.

PICTORIAL.–Pictorial illustrations normally indicate physical appearance. They may present details concerning the location, size, construction, physical relationships of size and location, or parts arrangement. They appear throughout manuals of all types, and are useful for locating and identifying systems, equipments, components, or parts. They are used in connection with installations, inspection, servicing, operation, adjustment, calibration, troubleshooting, and repair functions.

Pictorial illustrations may be accurately detailed representations, or they may be merely generalized indications, depending on their purpose. They may be photographs, halftone or shaded sketches, or line drawings.

CUTAWAY VIEW.–A cutaway view is an illustration used to show some detail of construction which would be extremely difficult or impossible to show by conventional pictorial views. It is often used in connection with discussions of physical construction and the operation of mechanical devices. It is frequently used in assembly diagrams and in construction details.

LOCATION AND DIMENSION.–Location diagrams are used to show physical position relationships, and may or may not be sufficiently detailed to show physical appearance. They are primarily useful for familiarization, and are commonly used in the Illustrated Parts Breakdown Manual (IPB), and in the Operation and Maintenance Instructions for equipments.

Dimension diagrams denote physical size and distance. They are useful in planning the layout of bench stations, making equipment installations, or packing materials for reshipment. They are frequently used in the general information sections of technical manuals, and in those sections devoted to familiarization, installation, and shipment. They are also frequently found in change-type technical directives.

Location and/or dimension diagrams may be combined with other type illustrations, thus providing additional details without increasing the number of illustrations.

ASSEMBLY DIAGRAMS.–Assembly diagrams provide details of construction which are useful in assembling parts into a unit. They are also useful in explaining the operation of mechanical or electromechanical devices.

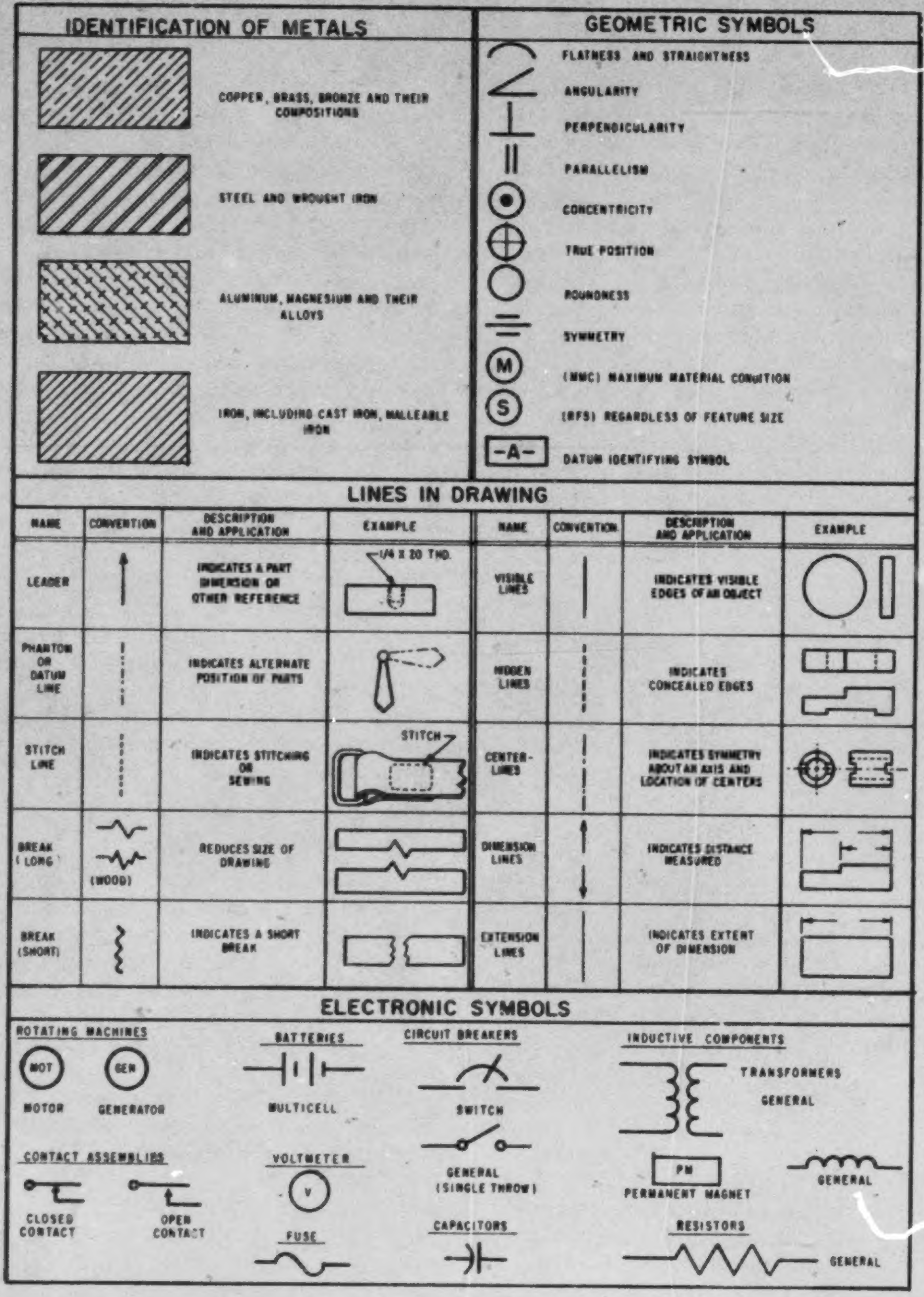
Block Diagrams

Block diagrams are used to present a generalized explanation of overall functional operation, and do not show physical shape, size, or location. They range from very simple to very complex, depending on the type equipment, the quantity and quality of details to be covered, and the purpose for which the information is included. They are found in nearly all manuals dealing with basic or detailed theory of operation, whether of relatively simple subassemblies or of very large and complex systems. The more complex the equipment, the more probable the need for block diagrams.

Many block diagrams are used in connection with electromechanical devices, as well as with electrical or mechanical systems. Proper use of this type diagram helps increase understanding of functional relationships and operation.

SYMBOLS.–Since block diagrams are used mainly to provide a general analysis of functional operation, symbols are generally used to represent individual circuits or functional components. In order to make maximum use of block diagrams, it is essential to recognize the symbols and to understand their meanings and limitations. Figure 5-7 contains some of the common symbols found on block diagrams.

SIGNAL FLOW.–One special type of block diagram is called the signal flow diagram or signal flow chart. It is usually used in connection with overall operation of complicated systems such as power distribution systems. It includes all features normally associated with block diagrams; and in addition, it includes considerable detail regarding signal paths, signal waveshape, timing sequence and relationships, magnitudes of potentials or signals, frequencies, etc.


IDENTIFICATION OF METALS
COPPER, BRASS, BRONZE AND THEIR COMPOSITIONS
STEEL AND WROUGHT IRON
ALUMINUM, MAGNESIUM AND THEIR ALLOYS
IRON, INCLUDING CAST IRON, MALLEABLE IRON
GEOMETRIC SYMBOLS
FLATNESS AND STRAIGHTNESS
ANGULARITY
PERPENDICULARITY
PARALLELISM
CONCENTRICITY
TRUE POSITION
ROUNDNESS
SYMMETRY
M
(MMC) MAXIMUM MATERIAL CONDITION
S
(RFS) REGARDLESS OF FEATURE SIZE
-A-
DATUM IDENTIFYING SYMBOL
LINES IN DRAWING
NAME
CONVENTION
DESCRIPTION AND APPLICATION
EXAMPLE
LEADER
INDICATES A PART DIMENSION OR OTHER REFERENCE
1/4 X 20 THD.
PHANTOM OR DATUM LINE
INDICATES ALTERNATE POSITION OF PARTS
STITCH LINE
INDICATES STITCHING OR SEWING
STITCH
BREAK (LONG)
(WOOD)
REDUCES SIZE OF DRAWING
BREAK (SHORT)
INDICATES A SHORT BREAK
VISIBLE LINES
INDICATES VISIBLE EDGES OF AN OBJECT
HIDDEN LINES
INDICATES CONCEALED EDGES
CENTER-LINES
INDICATES SYMMETRY ABOUT AN AXIS AND LOCATION OF CENTERS
DIMENSION LINES
INDICATES DISTANCE MEASURED
EXTENSION LINES
INDICATES EXTENT OF DIMENSION
ELECTRONIC SYMBOLS
ROTATING MACHINES
MOT
GEN
MOTOR
GENERATOR
BATTERIES
MULTICELL
CIRCUIT BREAKERS
SWITCH
GENERAL (SINGLE THROW)
INDUCTIVE COMPONENTS
TRANSFORMERS
GENERAL
PM
PERMANENT MAGNET
GENERAL
CONTACT ASSEMBLIES
CLOSED CONTACT
OPEN CONTACT
VOLTMETER
V
FUSE
CAPACITORS
RESISTORS
GENERAL

227.25

Figure 5-7.—Symbols.

Wiring Diagrams

The wiring diagram presents detailed circuitry information concerning electrical and electronic systems. A master wiring diagram is a single diagram that shows all the wiring in a complete system. In most cases, this diagram would prove to be too large to be usuable; it is normally broken down into logical functional sections, each of which may be further subdivided into circuit diagrams. By breaking a system into individual circuit diagrams, each individual circuit may be presented in greater detail. The increased detail provides for easier circuit tracing, testing, and maintenance.

Wiring diagrams fall into two basic classes–chassis wiring and interconnecting diagrams–each with specific purposes and many variations in appearance (depending on application). Wiring diagrams are not generally used for discussion of theory of operation of specific circuits.

WIRE AND CABLE SPECIFICATIONS.–An important part of electrical maintenance is to be able to determine the correct wire or cable for a particular maintenance task. To do this, the maintenance manual should first be consulted since it normally lists the wire used in a given piece of equipment.

CABLE CONSTRUCTION.–Cable construction diagrams present details concerning the fabrication and construction of cables. These details usually include designation of the type connectors or terminals, the identification of wires for each terminal, method of connecting wire to terminal, potting requirements, length of wires, lacing or sleeving specifications, and any other specifications or special considerations involved.

CABLE ROUTING.–Diagrams of major systems generally include an isometric shadow outline of the entire unit, showing the approximate location of equipment components and the physical routing of interconnecting cables. A cable, regardless of the number of conductors, is represented on an isometric wiring diagram as a single line; no attempt is made to show individual connections at equipment or in connection boxes. An isometric type drawing thus shows at a glance a picture of the layout of the entire system.

WIRE AND CABLE IDENTIFICATION CODING.–To facilitate maintenance, all wiring is identified on the wiring diagrams exactly as marked in the unit. Identification of each wire is coded by a combination of letters and numbers imprinted on the wire at prescribed intervals along its entire run. Figure 5-8 and the accompanying discussion explain the code used in wiring installation. Complete details are to be found in the latest revision of MIL-W-5088C.

The unit number (shown in dashed outline) is used only in those cases having more than one given unit installed in an identical manner in the same equipment. The wiring concerned with the first such unit bears the prefix 1, and corresponding wires for the second unit have exactly the same designation except for the prefix 2, etc.

The circuit function letter identifies the basic function of the unit. The ASM will be primarily concerned with function letters "X" and "P"; "X" denotes ac power, and "P" denotes dc power.

Each wire within a given circuit function group is assigned a separate wire number. Wires that are segmented by the use of splices, plug and receptacle connectors, terminal strip tie points, etc., are given a letter segment designation. Passage through a switch, relay, circuit breaker, etc., requires assignment of a new number. A suffix is added to designate the phase (or ground) in 3-phase ac power wiring.

AUTOMOTIVE WIRE IDENTIFICATION.–Most automotive vehicle wiring is made up into a harness with all leads coming out at the proper places and with the correct lengths to connect to the accessories. This simplifies the wiring of the automotive vehicle and serves to protect the wiring. To permit easy identification of the various leads, a color code in the insulation is widely used. The ASM should consult the applicable manual or handbook for the proper selection of wiring harness and the proper color

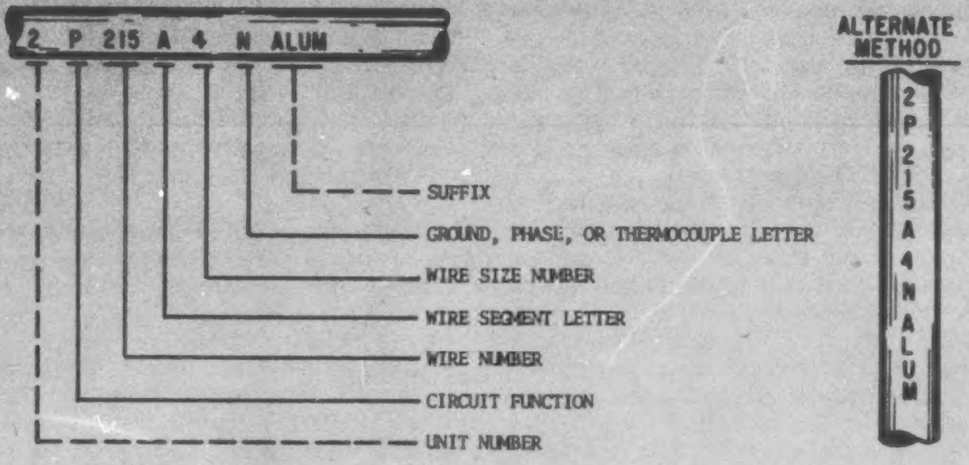


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Figure 5-8.—Examples of wire identification coding.

code for the vehicle which he is maintaining. A typical automotive color code is listed as follows:

1. RED LEAD—used to identify wires that are connected to the battery and are not fused, and wiring between the generator and regulator, or between the ammeter and circuit breaker/fuse.

2. RED LEAD WITH YELLOW TRACER—used for the primary ignition lead.

3. RED LEAD WITH BLACK TRACER—used between the ammeter and battery.

4. YELLOW LEAD—used in horn and light circuits and is fused.

5. BROWN LEAD WITH BLACK TRACER—used for all ground connections except battery ground.

6. BLACK LEAD—used to connect tail light to light switch.

7. BLACK LEAD WITH RED TRACER—used in the headlight circuit for high or bright beam.

8. GREEN LEAD—used in the headlight circuit for low or dim beam.

Schematics

The major purpose of the schematic diagram is to establish the operation of a particular system. It is not drawn to scale, and it shows none of the actual construction details of the system (such as a physical location within the equipment, physical layout of components, wire routing, or any other physical detail) not essential to understanding the operation.

Schematic drawings differ from block diagrams in that they present more detail. Whereas the block diagram deals with functional units of the system, the schematic diagram indicates each individual part which contributes to the functional operation.

SIMPLIFIED SCHEMATICS.—In large or complex equipments, a complete schematic drawing may be too large for practical use. For this reason, most technical manuals present partial or simplified schematics for individual units.

Simplified schematics normally omit parts and connections which are not essential to understanding unit operation. In studying or troubleshooting equipment, the ASM frequently must make his own simplified drawings. In these cases he should include only those items that contribute to the purpose of the drawing, but he should take care to include all such items. In using the schematic drawings throughout this course (and those in technical manuals, textbooks, and other publications), many techniques for simplifying schematics will become apparent. Special attention should be paid to those techniques found useful by the individual maintenance man–they can be extremely important tools in his work.

ELECTROMECHANICAL DRAWINGS.–Electromechanical devices are common in automotive systems. For a complete understanding of these units, neither an electrical drawing nor a mechanical drawing would be adequate–and confusion could result from the use of two drawings. Therefore a combination type drawing, using some aspects of each component type, is used. These drawings are usually simplified both electrically and mechanically, and only those items essential to the operation are indicated on the drawing.

CHARTS AND TABLES

Charts and tables of many types are used throughout all types of technical publications to present factual data in a clear and concise form. As the terms are used in this discussion, a chart is used to present information in lists, pictures, tables, or diagrams; a table is one type of chart, and is used to present or list information in a very condensed form.

Tables prove valuable in instances when the same general type of information is to be presented with respect to numerous items. The corresponding details for the items may be listed in columns, arranged so that reading across will present details regarding a specific item, while reading down will present a comparison of items with respect to a certain detail. One very common and useful table of this type is represented by table 5-1 shown earlier in this chapter.

Plumbing

Rigid and flexible tubing are the two most common types used in ground support equipment. These tubes are manufactured in many different sizes; sizing is usually determined by outside diameter and ranges from 1/8 inch to 2 inches. The amount of pressure that a tube can safely withstand is determined by the type of material and the wall thickness. Use caution when replacing or repairing tubing to ensure that the proper type is used. Detailed information on tubing and tubing repairs may be found in Aircraft Structural Hardware, NA 01-1A-8.

RIGID TUBING.–Rigid metal tubes are widely used for fuel, oil, coolant, oxygen, instrument, hydraulic, and vent lines. Tubing of copper, corrosion-resistant steel (stainless steel), and aluminum alloy is used. The basic tube material may be identified by either visual inspection or, as in the case of aluminum alloys, the actual alloy designation may be stamped on the surface of the tubing.

RIGID LINE IDENTIFICATION.–Each rigid line is identified by bands of paint or strips of tape around the line near each fitting. These identifying media are applied at points where they may be easily seen. Various other information is also applied to the lines.

Identification tapes are applied to all lines less than 4 inches in diameter except cold lines, hot lines, lines in oily environment, and lines in engine compartments where there is a possibility of the tape being drawn into the engine intake. In these cases, and all others where tapes should not be used, painted identification is applied to the lines.

Identification tape codes indicate the function, contents, hazards, direction of flow, and pressure in the fluid line. These tapes are applied in accordance with MIL-STD-1247. This standard was issued in order to standardize rigid line identification throughout the Department of Defense.

The function of a line is identified by use of a tape, approximately 1 inch wide, upon which word(s), color(s), and geometric symbols are printed. Functional identification markings, as provided in MIL-STD 1247, are the subject of an international standardization agreement. Three-fourths of the total width on the left side of the tape has a code color or colors which indicate one function only per color or colors.

The function of the line is printed in English across the colored portion of the tape; therefore, even a non-English-speaking person can troubleshoot or maintain the system if he knows the code but cannot read English. The right-hand one-fourth of the functional identification tape contains a geometric symbol which is different for every function. This is to ensure that all technicians, whether English speaking or not, who may be colorblind may still be able to positively identify the line function by means of the geometric design rather than by the color(s) or word(s). Figure 5-9 is a listing, in tabular form, of functions and their associated identification media as used on the tapes.

The identification-of-hazards tape shows the hazard associated with the contents of the line. Tapes used to show hazards are approximately one-half inch wide, with the abbreviation of the hazard contained in the line printed across the tape. There are four general classes of hazards found in connection with fluid lines. These hazards are outlined in the following paragraphs.

Flammable Material (FLAM). The hazard marking "FLAM" is used to identify all

FUNCTION	COLOR	SYMBOL
Fuel	Red	✦
Rocket Oxidizer	Green, Gray	☽
Rocket Fuel	Red, Gray	✦☽
Water Injection	Red, Gray, Red	∨
Lubrication	Yellow	▚
Hydraulic	Blue, Yellow	●
Solvent	Blue, Brown	≣
Pneumatic	Orange, Blue	X
Instrument Air	Orange, Gray	⚡
Coolant	Blue	∽
Breathing Oxygen	Green	▬
Air Conditioning	Brown, Gray	⁂
Monopropellant	Yellow, Orange	T
Fire Protection	Brown	◆
De-Icing	Gray	▲▲
Rocket Catalyst	Yellow, Green	‖‖
Compressed Gas	Orange	▰
Electrical Conduit	Brown, Orange	↯
Inerting	Orange, Green	✚✚

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Figure 5-9.—Functional identification tape data.

materials known ordinarily as flammables or combustibles.

Toxic and Poisonous Materials (TOXIC). A line identified by the word "TOXIC" contains materials which are extremely hazardous to life or health.

Anesthetics and Harmful Materials (AAHM). All materials productive of anesthetic vapors and all liquid chemicals and compounds hazardous to life and property, but not normally productive of dangerous quantities of fumes or vapors, are in this category.

Physically Dangerous Materials (PHDAN). A line which carries material which is not dangerous within itself, but which is asphyxiating in confined areas or which is generally handled in a dangerous physical state of pressure or temperature, is identified by the marking "PHDAN".

Table 5-5 lists some of the fluids with which the ASM may be required to work and the hazards associated with each.

Table 5-5.—Hazards associated with various fluids

Contents	Hazard
Air (under pressure)	PHDAN
Alcohol	FLAM
Carbon dioxide	PHDAN
Freon	PHDAN
Gaseous oxygen	PHDAN
Liquid nitrogen	PHDAN
Liquid oxygen	PHDAN
LPG (liquid petroleum gas)	FLAM
Nitrogen gas	PHDAN
Oils and greases	FLAM
JP-4	FLAM
Trichlorethylene	AAHM

FLEXIBLE HOSE.—Flexible hose assemblies, such as rubber and Teflon, consist of lengths of hose that are coupled with threaded end fittings. They may be divided into two major groups—high pressure and low pressure, according to their application.

The specifications of a flexible hose may be obtained by interpreting the identification code that is printed on the hose. This identification, which is a series of dots and dashes, gives the hose size, temperature range, and date of manufacture in quarter of year and year. Refer to NA 01-1A-8 for a detailed discussion of flexible hose identification.

The size of Teflon hose is determined in the same way the size of rubber hose is determined.

Teflon hose, like rubber hose, has definite limits and particular characteristics that demand understanding and attention in the general handling during installation and removal.

CHAPTER 6

RECIPROCATING COMBUSTION ENGINES

As an Aviation Support Equipment Technician M (Mechanical), you should know the important parts of an internal combustion engine and how they operate. An engine is a machine that converts heat energy to mechanical energy. The heat energy is derived from fuel, and the mechanical energy is used to do work. Figure 6-1 shows, in simplified form, an external and an internal combustion engine. An internal combustion engine is a machine that, by burning fuel inside the machine, produces mechanical energy that does the work; for example, an automobile engine. An example of an external combustion engine is a steam engine, because the heat energy (steam) is produced away from the engine.

All internal combustion engines, no matter what they use for fuel, are basically the same. They all rely on air, fuel, and ignition to operate. All three are essential, and the engine will not operate with any one missing. The fuel has the potential heat energy; the air has the oxygen necessary for burning the fuel; and ignition starts the combustion needed to develop the mechanical energy.

Internal combustion engines are classified by type of fuel used, type of cooling employed, strokes in the cycle, and valve and cylinder arrangement. The fuel used is gasoline or diesel. To withstand the higher temperatures and pressures generated, the diesel engine is heavier and built stronger than the gasoline engine. The method of getting fuel to the cylinders is different in the two engines, also the method of igniting the fuel. These differences are explained later in this training manual.

Internal combustion engines are also classified as air- or liquid-cooled. The cylinders of a liquid-cooled engine are surrounded by jackets through which the cooling fluid circulates. These jackets are an integral part of the engine block. The cylinders of an air-cooled

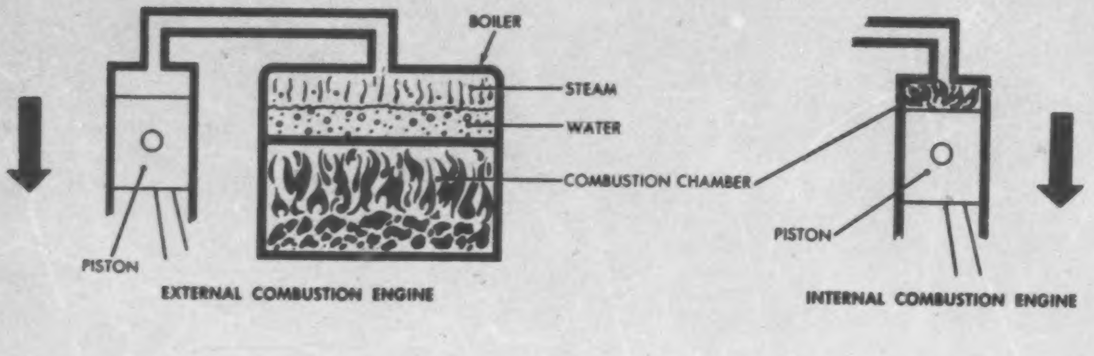

Figure 6-1.—Simple external and internal combustion engine.

engine are made individually or in groups of two and are bolted to the block. They have closely spaced fins completely around the barrel of the cylinder, that provide an increased surface area from which heat can dissipate. Other than these differences, engines that are air or liquid-cooled are essentially the same.

The cylinder and valve arrangement can be different in internal combustion engines. Cylinders may be inline–with all cylinders in a straight line above the crankshaft; V–with two rows of cylinders in a V shape above the crankcase; or horizontally opposed–with the cylinders mounted in two side rows opposite a central crankshaft. The valve classification is according to the position of the valves–in the block, in the head, or one in the head and one in the block. Later in this chapter the placement of the cylinders and valves is discussed.

Four-stroke cycle and two-stroke cycle engines are explained later in this chapter.

When working with internal combustion engines, you, as an ASM, need to become familiar with a few engineering terms. WORK, the product of an engine, is the movement of an object against an opposing force. When an object is lifted from the ground, work is done on the object. The opposing force is gravity. If an object weighing 1 pound is lifted 1 foot, 1 foot-pound of work is done. When an object has ENERGY, it has the ability to do work. Fuel has potential energy that can be released to do work. One method of releasing the fuel energy is by use of an engine. Energy is stored in an object when work is performed on it; for example, the energy stored in an object lifted from the ground depends on the height to which it is lifted. A 1-pound weight will do 1 foot-pound of work on striking the ground if released 1 foot from the ground.

POWER is the rate at which work is done. More power is needed to do work rapidly than to do work slowly. An engine is power rated on the amount of work it can do per minute. HORSEPOWER is the measure of the work capacity of an engine. One horsepower is 33,000 foot-pounds of work per minute. If 100 pounds were lifted 330 feet or 330 pounds were lifted 100 feet in 1 minute, 1 horsepower would be required. The formula for obtaining horsepower is

$$\text{hp} = \frac{\text{ft-lb per min}}{33{,}000} \text{ or } \frac{L \times W}{33{,}000 \times t}$$

L = length in feet, through which W is moved

W = force, in pounds, that is exerted through distance L

t = time, in minutes, required to move W through L

A device used to measure the horsepower of an engine is the dynamometer, and is explained in chapter 2.

When the lid of a jar is loosened or tightened, a twisting force or TORQUE is applied to it. Torque is applied to a wrench when you use it to loosen or tighten a nut. Torque is measured by pound-feet as explained in chapter 2. Torque is not work or power, because it does not have motion. Instead, it is the turning effort the engine applies to the wheels through the gears and shafts. FRICTION is the resistance to motion between two objects that are in contact with each other. After washing and drying your hands, it takes effort to rub your first finger and thumb together. If a little oil or water is placed between them, much less effort is required to rub them together. The oil or water acts as a lubricant to help eliminate friction. Friction is used in the brakes and clutches of automotive equipment. Friction in the remainder of the engine is undesirable, because it decreases the power output by using some of the energy of the engine to overcome it.

INERTIA causes a material object to resist any change of speed or direction of travel. A motionless object tends to remain at rest, and a moving object tends to keep moving at the same speed and in the same direction. Force is needed to start an object moving or make it move faster, slow down, stop, or change direction when moving in a straight line. The engine of an automobile makes it start to move and move faster. The breaks slow the forward motion and stop the automobile. The steering mechanism turns the automobile. All of these overcome inertia.

The EFFICIENCY of an engine is the relationship between power developed in the cylinders and the power delivered. The power developed is called indicated horsepower and can be determined by a formula using the pressure on the piston, area of the piston head, length of the power stroke, strokes per minute, number of cylinders, and 33,000 foot-pounds per minute. The power delivered is called brake horsepower and can be measured by a dynamometer. The difference is the horsepower used by the engine in overcoming the friction of moving parts, drawing in fuel, expelling exhaust, driving oil and fuel pumps, and other essential accessories. The mechanical efficiency of an engine is the brake horsepower divided by the indicated horsepower and is written as a percentage.

The size of an engine cylinder is usually indicated in terms of bore and stroke. (See fig. 6-2.) BORE is the inside diameter of the cylinder, and STROKE is the distance the piston travels in the cylinder. A 3 x 4 cylinder indicates that the cylinder diameter (bore) is 3 inches and the stroke is 4 inches. These measurements can be used to determine PISTON DISPLACEMENT which is the volume that the piston displaces as it moves from one end of the stroke to the other. The formula is

$$V = \pi R^2 \times S$$

$V =$ piston displacement (volume)

$R =$ radius (one-half the diameter) of the cylinder

$\pi R^2 =$ area of a circle

$S =$ length of the stroke

For the above cylinder, using 3.14 as π the piston displacement would be 28.26 cubic inches.

The COMPRESSION RATIO of an engine is a measurement of how much the air-fuel mixture is compressed on the compression stroke of the piston in the cylinder. This is determined by dividing the volume of the cylinder with the piston at the bottom of the stroke by the volume of the cylinder with the piston at the top of the stroke. For example, if the volume of an engine cylinder is 60 cubic inches with the piston at the bottom of the stroke and 10 cubic inches with the piston at the top of the stroke, then the compression ration is 6:1. The part of the cylinder above the piston when it is at the top of the stroke is called the COMBUSTION CHAMBER.

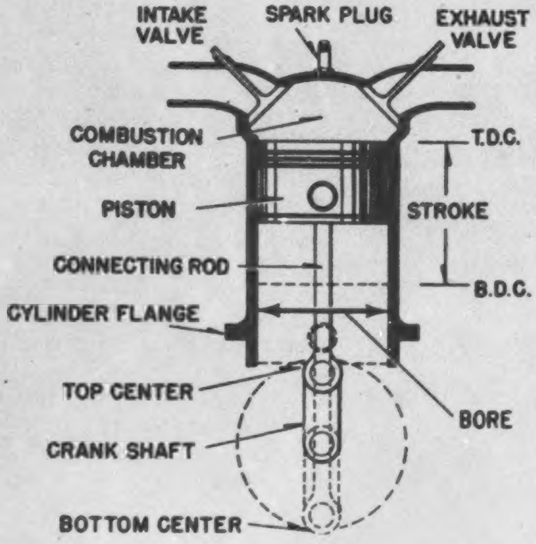

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Figure 6-2.—Bore and stroke of an engine cylinder.

BASIC ENGINE STROKES

Each movement of the piston from top to bottom or from bottom to top is called a stroke. The piston takes two strokes (an upstroke and a downstroke) as the crankshaft makes one complete revolution. When the piston is at the top of a stroke, it is said to be at top dead center (TDC). When the piston is at the bottom of a stroke, it is said to be at bottom dead center (BDC). These positions are called rock positions and will be discussed further in this chapter under "Timing." See figure 6-3 and figure 6-4.

The basic engine you have studied so far has had no provisions for getting the fuel-air mixture into the cylinder or burned gases out of the cylinder. There are two openings in the enclosed end of a cylinder. One of the openings, or ports, permits the mixture of air and fuel to enter and the other port permits the burned gases to escape from the cylinder. The two ports have valves assembled in them. These valves, actuated by the camshaft, close off either one or the other of the ports, or both of them, during various stages of engine operation. One of the valves, called the intake valve, opens to admit a mixture of fuel and air into the cylinder. The other valve, called the exhaust valve, opens to allow the escape of burned gases after the fuel-and-air mixture has burned. Later on you will learn more about how these valves and their mechanisms operate.

The following paragraphs give a simplified explanation of the action that takes place within the engine cylinder. This action may be divided into four parts: the intake stroke, the compression stroke, the power stroke, and the exhaust stroke. Since these strokes are easy to identify in the operation of a four-cycle engine, that engine is used in the description. This type of engine is also called a four-stroke-Otto-cycle engine, because it was Dr. N.A. Otto who, in 1876, first applied the principle of this engine.

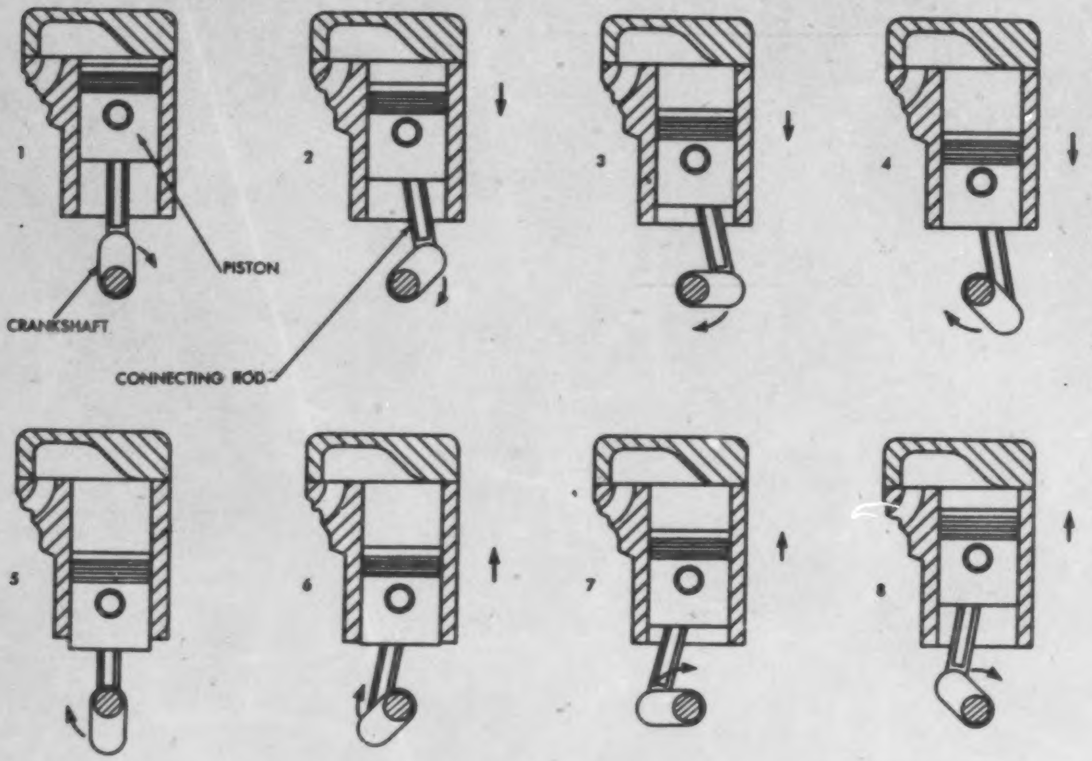

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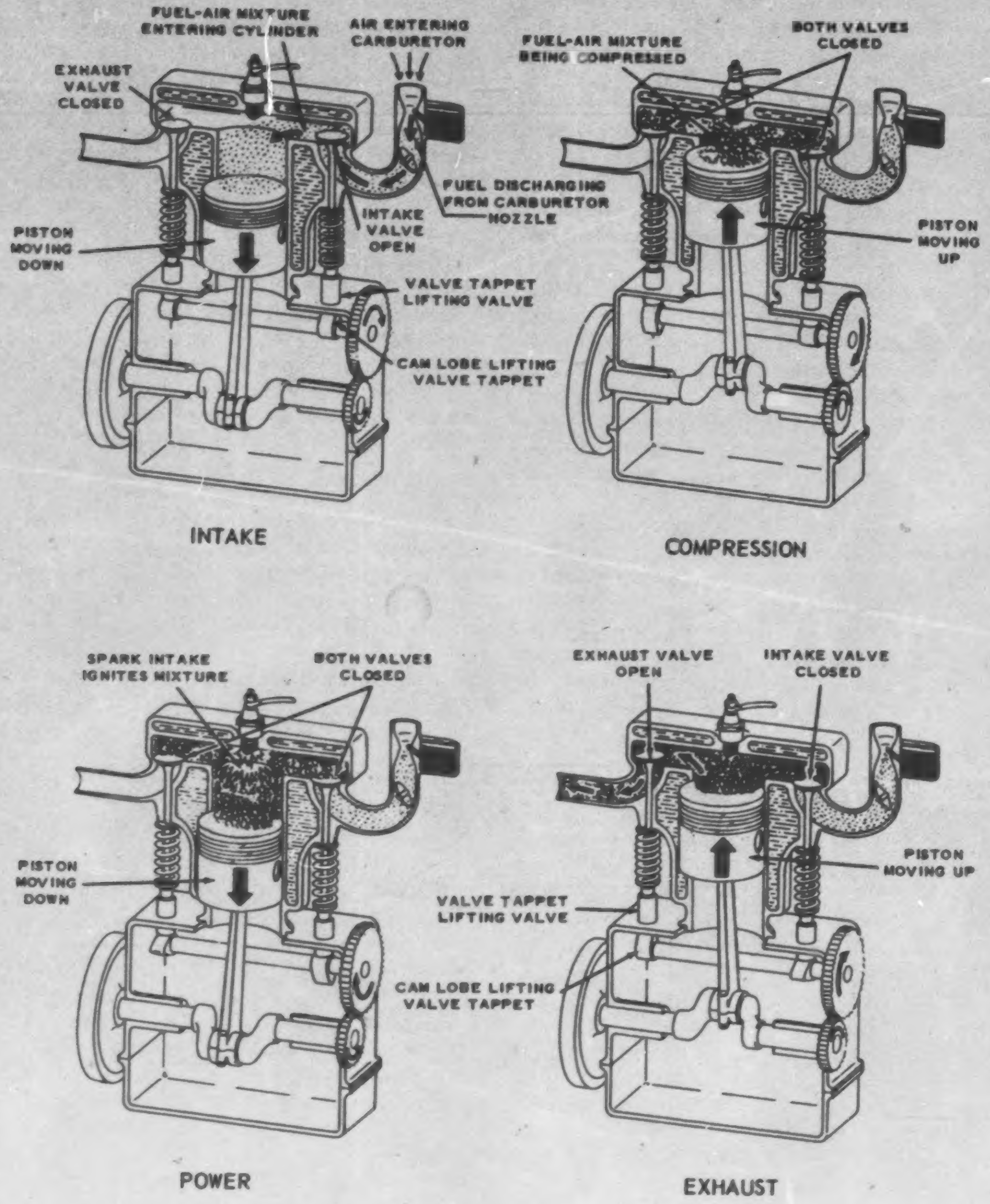
Figure 6-3.—Relationship of piston, connecting rod, and crank on crankshaft as crankshaft turns one revolution.


FUEL-AIR MIXTURE ENTERING CYLINDER
AIR ENTERING CARBURETOR
EXHAUST VALVE CLOSED
FUEL DISCHARGING FROM CARBURETOR NOZZLE
INTAKE VALVE OPEN
PISTON MOVING DOWN
VALVE TAPPET LIFTING VALVE
CAM LOBE LIFTING VALVE TAPPET
INTAKE
FUEL-AIR MIXTURE BEING COMPRESSED
BOTH VALVES CLOSED
PISTON MOVING UP
COMPRESSION
SPARK INTAKE IGNITES MIXTURE
BOTH VALVES CLOSED
PISTON MOVING DOWN
POWER
EXHAUST VALVE OPEN
INTAKE VALVE CLOSED
PISTON MOVING UP
VALVE TAPPET LIFTING VALVE
CAM LOBE LIFTING VALVE TAPPET
EXHAUST

54.19

Figure 6-4.—Four-stroke cycle in a gasoline engine.

INTAKE STROKE

The first stroke in the sequence is called the intake stroke (fig. 6-4). During this stroke, the piston is moving downward and the intake valve is open. This downward movement of the piston produces a partial vacuum in the cylinder, and air and fuel rush into the cylinder past the open intake valve. This is somewhat the same effect as when you drink through a straw. A partial vacuum is produced in the mouth and the liquid moves up through the straw to fill the vacuum.

COMPRESSION STROKE

When the piston reaches bottom dead center at the end of the intake stroke and is therefore at the bottom of the cylinder, the intake valve closes. This seals the upper end of the cylinder. As the crankshaft continues to rotate, it pushes up, through the connecting rod, on the piston. The piston is therefore pushed upward and compresses the combustible mixture in the cylinder; this is called the compression stroke (fig. 6-4). In gasoline engines, the mixture is compressed to about one-eighth of its original volume. (In a diesel engine the mixture may be compressed to as little as one-sixteenth of its original volume.) This compression of the air-fuel mixture increases the pressure within the cylinder. Compressing the mixture in this way makes it more combustible; not only does the pressure in the cylinder go up, but the temperature of the mixture also increases.

POWER STROKE

As the piston reaches top dead center at the end of the compression stroke and therefore has moved to the top of the cylinder, the compressed fuel-air mixture is ignited. The ignition system causes an electric spark to occur suddenly in the cylinder, and the spark sets fire to the fuel-air mixture. In burning, the mixture gets very hot and tries to expand in all directions. The pressure rises to about 600 or 700 pounds per square inch. Since the piston is the only thing that can move, the force produced by the expanding gases forces the piston down. This force, or thrust, is carried through the connecting rod to the crankpin on the crankshaft. The crankshaft is given a powerful twist. This is called the power stroke (fig. 6-4). This turning effort, rapidly repeated in the engine and carried through gears and shafts, will turn the wheels of a vehicle and cause it to move along the highway.

EXHAUST STROKE

After the fuel-air mixture has burned, it must be cleared from the cylinder. This is done by opening the exhaust valve just as the power stroke is finished and the piston starts back up on the exhaust stroke (fig. 6-4). The piston forces the burned gases out of the cylinder past the open exhaust valve. The four strokes (intake, compression, power, and exhaust) are continuously repeated as the engine runs.

ENGINE CYCLES

To produce sustained power an engine must accomplish a definite series of operations over and over again. All you have to do is follow one series of events–intake, compression, power, and exhaust–until they repeat themselves. This one series of events is called a cycle.

Most engines of today are four-cycle engines. What is meant is four-stroke-cycle, but our habit of abbreviating has eliminated the middle word. Just the same, when you see four-cycle it means that there are four strokes of the piston, two up and two down, to each cycle. Then it starts over again on another cycle of the same four strokes.

TWO-CYCLE ENGINE

In the two-cycle engine, the entire cycle of events (intake, compression, power, and exhaust) takes place in two piston strokes.

A two-cycle engine is shown in figure 6-5. Every other stroke in this engine is a power stroke. Each time the piston moves down it is on the power stroke. Intake, compression, power, and exhaust still take place, but they are completed in just two strokes. In figure 6-5 the intake and exhaust ports are cut into the cylinder wall instead of being placed at the top of the combustion chamber as in the four-cycle engine. As the piston moves down on its power stroke, it first uncovers the exhaust port to let

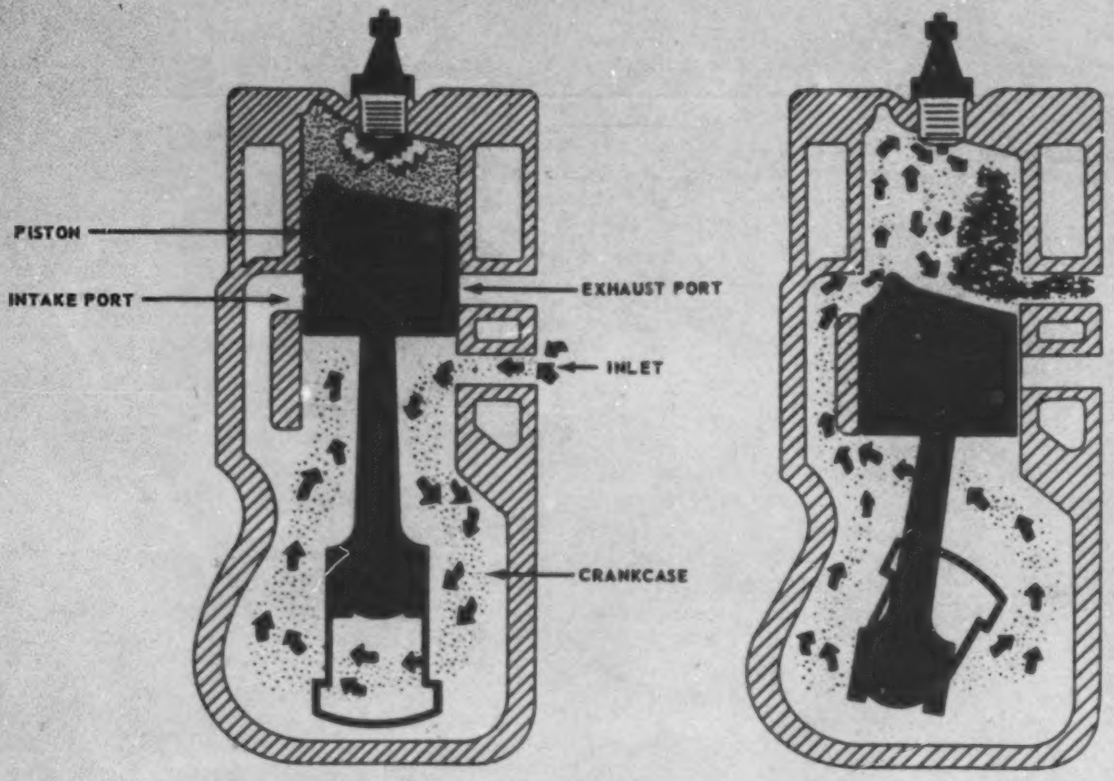


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Figure 6-5.—Events in a two-stroke cycle engine.

burned gases escape and then uncovers the intake port to allow a new fuel-air mixture to enter the combustion chamber. Then, on the upward stroke, the piston covers both ports and, at the same time, compresses the new mixture in preparation for ignition and another power stroke.

In the engine shown in figure 6-5 the piston is shaped so that the incoming fuel-air mixture is directed upward, thereby sweeping out ahead of it the burned exhaust gases. Also, there is an inlet into the crankcase through which the fuel-air mixture passes before it enters the cylinder. This inlet is opened as the piston moves upward, but it is sealed off as the piston moves downward on the power stroke. The downward moving piston slightly compresses the mixture in the crankcase, thus giving the mixture enough pressure to pass rapidly through the intake port as the piston clears this port. This improves the sweeping-out, or scavenging, effect of the mixture as it enters and clears the burned gases from the cylinder through the exhaust port.

FOUR-CYCLE vs TWO-CYCLE ENGINES

You have probably noted that the two-cycle engine produces a power stroke every crankshaft revolution; the four-cycle engine requires two crankshaft revolutions for each power stroke. It might appear then that the two-cycle could produce twice as much power as the four-cycle of the same size, operating at the same speed. However, this is not true. With the two-cycle engine some of the power is used to drive the blower that forces the air-fuel charge into the cylinder under pressure. Also, the burned gases are not completely cleared from the cylinder. Additionally, because of the much shorter period the intake port is open (as compared to the period the intake valve in a four-stroke-cycle is open), a relatively smaller amount of fuel-air mixture is admitted. Hence, with less fuel-air mixture, less power per power stroke is produced as compared to the power produced in a four-stroke cycle engine of like size operating at the same speed and with other conditions being the same. To increase the amount of fuel-air mixture, auxiliary devices are used with the two-stroke engine to ensure delivery of greater amounts of fuel-air mixture into the cylinder.

MULTIPLE-CYLINDER ENGINES

The discussion so far in this chapter has concerned a single-cylinder engine. A single cylinder provides only one power impulse every two crankshaft revolutions in a four-cycle engine and is delivering power only one-fourth of the time. To provide for a more continuous flow of power, modern engines use four, six, eight, or more cylinders. The same series of cycles take place in each cylinder.

In a four-stroke cycle six-cylinder engine, for example, the cranks on the crankshaft are set 120 degrees apart, the cranks for cylinders 1 and 6, 2 and 5, and 3 and 4 being in line with each other (fig. 6-6). The cylinders fire or deliver the power strokes in the following order: 1-5-3-6-2-4. Thus the power strokes follow each other so closely that there is a fairly continuous and even delivery of power to the crankshaft.

BLOCKS

The engine block of most of the equipment you, as an ASM, will be required to service and repair is the basic frame of the engine. In liquid cooled engines, the block contains the cylinders, water passages used to circulate the water for cooling the cylinders, and the main bearing housing for the crankshaft when the crankcase and cylinder block are cast in one piece. All the accessories that help to make up an engine are attached to the block. Some blocks contain the valve ports to the cylinders and the passageways for the valves. The intake and exhaust manifolds may be bolted to the block. The camshaft is also supported in the block. A more detailed description of the block is given in chapter 13 of *Basic Machines*. Most of the maintenance of the

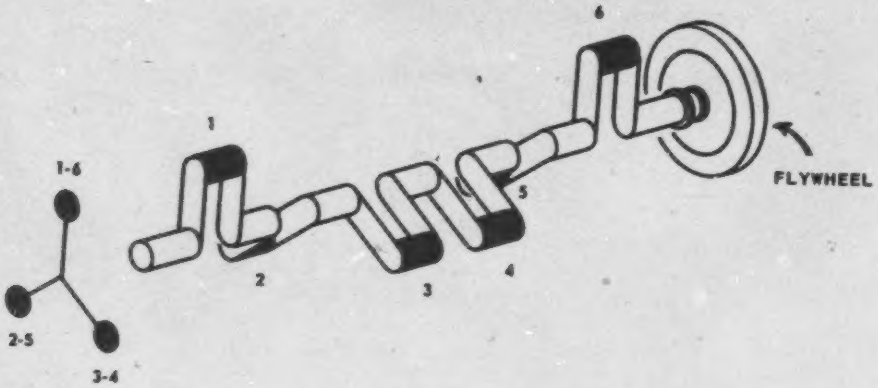


Figure 6-6.–Crankshaft for a six-cylinder engine. 81.42

block involves the cylinders, cooling system, crankshaft, and camshaft, and is covered later in this chapter. The part of the engine block that is not covered by accessories should be periodically wiped down and inspected for cracks and rust. The supports for the engine are either a part of the block or crankcase, or they are bolted to it.

CYLINDERS

The smooth inner surface of cylinders is achieved by grinding and/or boring. Since the piston moves up and down in the cylinder, the cylinder wall must be smooth and perfectly round. Wear-resistant metal alloy liners or sleeves serve as cylinder walls in most diesel engines and in a few gasoline engines. The liners can be replaced when they become rough or out-of-round. Liners can be either press fit or slip fit into the block. They are either wet-type or dry-type, depending on whether or not they come in contact with the coolant. Special precautions must be taken with the seals when installing the wet-type liner. Soap or brake fluid is recommended as a lubricant on the seals to prevent them from rolling or twisting.

Most of the wear on the side of the cylinder wall is caused by the pressure of the piston rings. Some wear is also caused by the side thrust of the piston and by dirt getting in the cylinder and acting as a grinding compound against the wall. Special gages and micrometers are used to measure the wear. *Tools and Their Uses,* NAVEDTRA 10085 (Series) explains how to use these tools. To determine if a new liner is needed, check the manufacturer's manual. On engines with no liner, the cylinder may need to be rebored to smooth it and make it round again. This may require oversized pistons and/or rings when the engine is again assembled.

On air-cooled engines the cylinders may be exposed to more readily dissipate the heat. In this case, one or two cylinders will usually have a bolted-on head that makes it easy to inspect a cylinder. The cylinder or cylinders may be in a separate unit that is bolted to the block. In this case, a cylinder base gasket is used between the cylinder assembly and the block. Refer to chapter 13 of *Basic Machines,* NAVEDTRA 10624 (Series), for more details on cylinders.

PISTONS

Because of the sealing quality of the piston rings, the piston becomes a moving wall in the cylinder. The piston (fig. 6-7) also acts as the

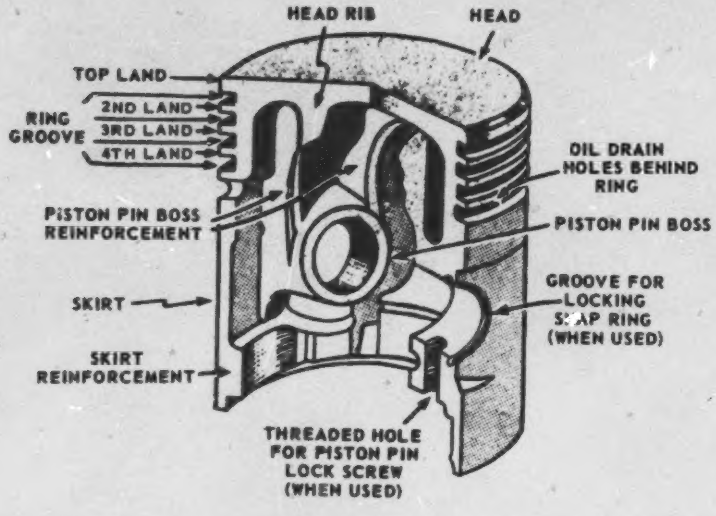

HEAD RIB
HEAD
TOP LAND
RING GROOVE
2ND LAND
3RD LAND
4TH LAND
OIL DRAIN HOLES BEHIND RING
PISTON PIN BOSS REINFORCEMENT
PISTON PIN BOSS
SKIRT
GROOVE FOR LOCKING SNAP RING (WHEN USED)
SKIRT REINFORCEMENT
THREADED HOLE FOR PISTON PIN LOCK SCREW (WHEN USED)

Figure 6-7.—Parts of a piston.

81.53

guide for the upper end of the connecting rod which transmits the force of combustion from the piston to the crankshaft. The piston is attached to the connecting rod by a piston pin (wrist pin) that passes through the upper end of the connecting rod and through bosses in the piston. The grooves near the top of the piston house the piston rings. The two top rings are usually compression rings that prevent gases from leaking by the piston on the compression and power strokes when the pressure is the greatest. Either one or two oil-regulating rings located below the compression rings scrape oil from the cylinder wall and return it to the crankcase. Piston rings are shown in figure 6-8.

The piston must stop at the end of each stroke and withstand the force of combustion. Therefore, it must be made of tough material, yet be light in weight. It must also be carefully balanced and weighted to overcome inertia and momentum at high speeds. The piston pin may be fastened to the piston or to the connecting rod, or not be fastened to either and be free floating. Since about one-third of the heat absorbed by the piston because of combustion is transmitted through the rings to the cylinder wall, piston rings are made of heat-resistant metal. Because the rings must maintain contact with the cylinder wall through their own spring action and withstand the constant wear against the wall, they must be very hard. Pistons, piston rings, and piston pins are described in more detail in chapter 13 of *Basic Machines.*

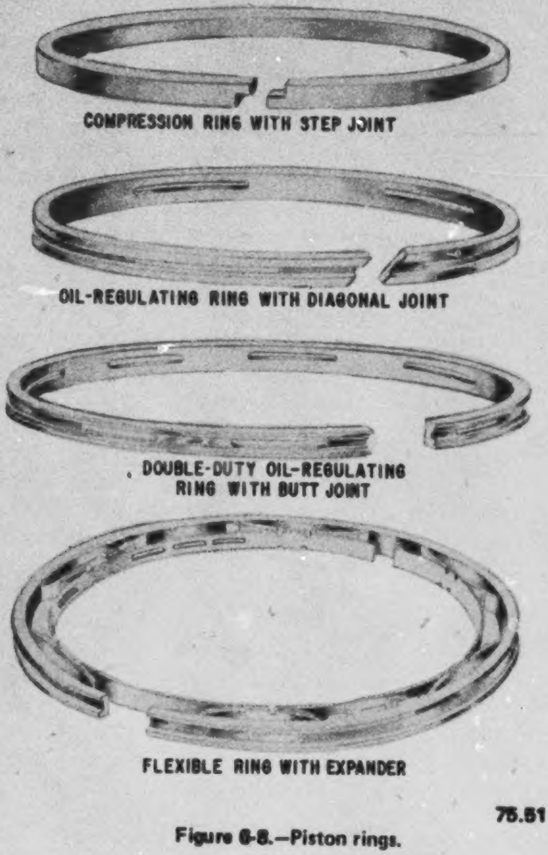

COMPRESSION RING WITH STEP JOINT
OIL-REGULATING RING WITH DIAGONAL JOINT
DOUBLE-DUTY OIL-REGULATING RING WITH BUTT JOINT
FLEXIBLE RING WITH EXPANDER
75.51

Figure 6-8.—Piston rings.

The purpose of the piston assembly is to seal the cylinder below the combustion chamber. If the piston is cracked or broken or the piston rings worn or broken, the desired seal is lost. When this happens, the piston or the rings must be replaced. The cylinder leakage tester used to determine this malfunction of the piston and rings has been covered in chapter 2 of this training manual.

To replace piston rings, the old rings must be carefully removed. Care must be used in removing the rings and in positioning the new rings not to scratch or gouge the grooves or the lands between the grooves. Piston lands are parts of the piston between the grooves and provide a seating surface for the sides of the rings.

Scratches and gouges can upset the balance of the piston and impair the purpose of the rings. The new rings can be spread enough to permit slipping them into the proper grooves. Since the rings are very hard, extreme care must be exercised not to spread them too much or they will break. A piston ring compressor is used to hold the rings to the cylinder size until the piston and rings can be pushed into the cylinder. To replace a cracked piston, the connecting rod must be disconnected from the crankshaft. Then the piston and connecting rod can be removed and the new piston installed.

CONNECTING RODS

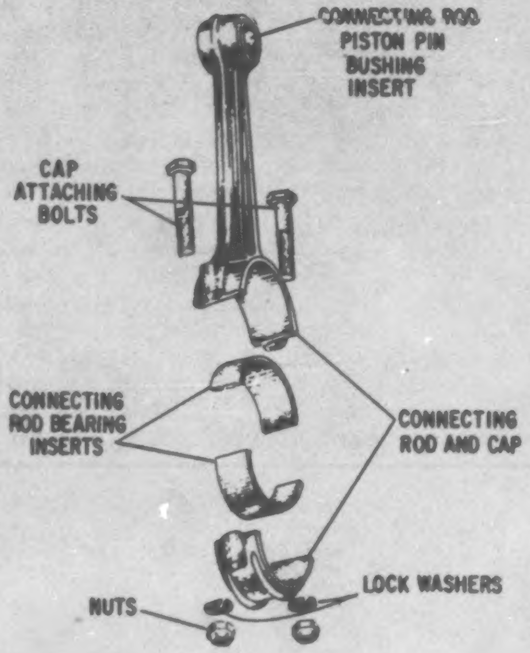
Connecting rods permit the force exerted on the piston during the power stroke to be transferred to the crankshaft. Therefore, they are forged from a steel alloy that is strong enough to withstand heavy loads without bending or twisting. Each end is constructed to hold bearings that fit on the piston pin at the top and on the crankshaft at the bottom end. (See chapter 13 of *Basic Machines* for more details on connecting rods.) Because connecting rods seldom break, most of the maintenance involves replacing the bearings or bearing inserts on the ends. Bearing inserts are made of bronze or similar material. The insert that contacts the piston pin is round and may need to be reamed out so the pin will fit snug but not tight. The insert that contacts the crankshaft is usually in two pieces that fit together when the connecting rod cap is bolted around the crankshaft to the connecting rod (fig. 6-9).

When the connecting rods are replaced, the connecting rod and cap are bolted together (fig. 6-9) over the bearing inserts that fit around the crankshaft. The nuts on the bolts must be tightened to a specific tension using a torque wrench. Be sure you obtain the correct tension from the maintenance manual and tighten each nut to that torque.

To maintain good engine balance, connecting rods are carefully matched in sets. When it becomes necessary to remove them, make sure they are marked so they can be replaced in the same order in which they were removed. In addition to the proper fit of the connecting rod bearings and the proper position of the connecting rod, the alignment of the rod must be correct. This means that the hole for the piston pin and the crankshaft must be precisely parallel. Equipment of acceptable accuracy for checking connecting rods is shown in figure 6-10. Every rod should be checked for proper alignment before it is installed in the engine. Misalignment may cause hard-to-locate noises in the engine.

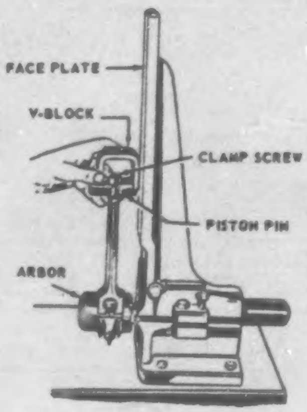
CRANKSHAFTS

The crankshaft (fig. 6-11) transforms the up and down motion of the piston and connecting rod to a rotary motion that drives the vehicle. To do this, the part where the connecting rod


CONNECTING ROD PISTON PIN BUSHING INSERT
CAP ATTACHING BOLTS
CONNECTING ROD BEARING INSERTS
CONNECTING ROD AND CAP
LOCK WASHERS
NUTS

227.29

Figure 6-9.—Connecting rod.

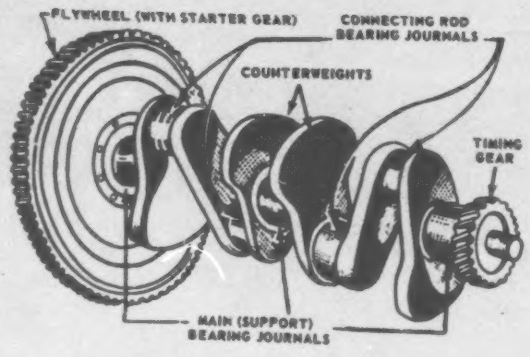


81.59

Figure 6-10.—Checking connecting rod alignment.

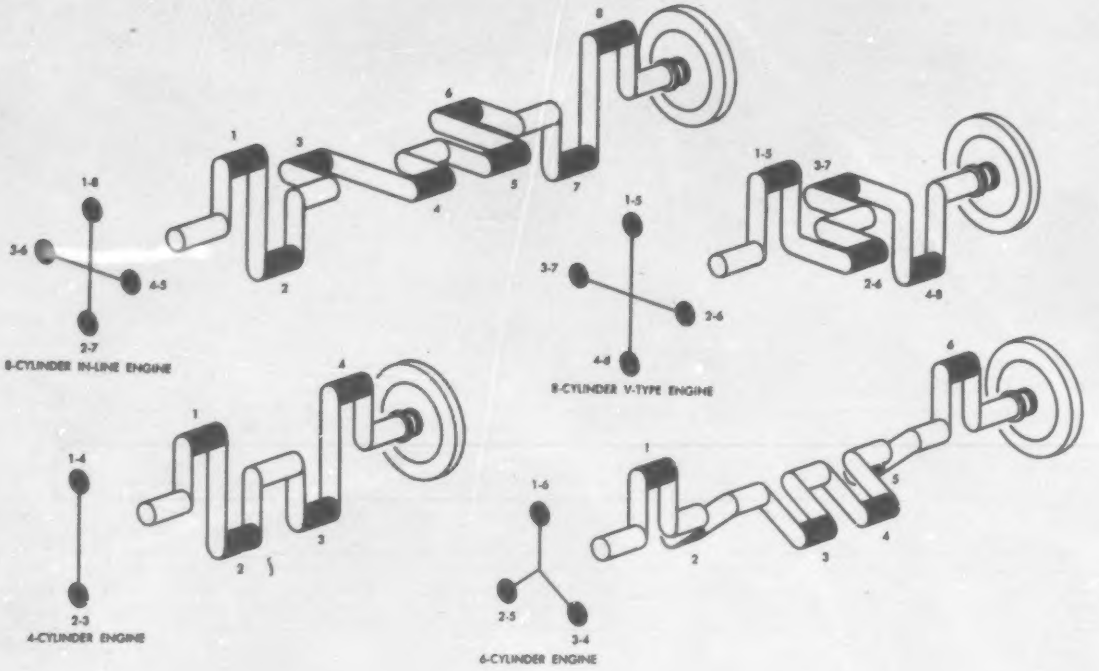
exerts the thrust is off the line going through the center of the crankshaft. Thus, the thrust acts like your arm when you turn a crank,—a speed handle for sockets, or a brace and bit. This offset part where the connecting rod fastens to the crankshaft is called the throw. Throws are situated so that they counterbalance each other (fig. 6-12). V-type engines have two connecting rods, one from each side, fastened to one crankshaft throw. To allow the rods to clear each other, one bank of cylinders is set ahead of the other.

Main bearings support the crankshaft on each end and from one to three places in between. The crankshaft is made of an alloy of steel and nickel, and the surfaces for the main and throw bearings are machined smooth. The


FLYWHEEL (WITH STARTER GEAR)
CONNECTING ROD BEARING JOURNALS
COUNTERWEIGHTS
TIMING GEAR
MAIN (SUPPORT) BEARING JOURNALS

75.81A

Figure 6-11.—Crankshaft of a 4-cylinder engine.


1-8
3-6
4-5
2-7
8-CYLINDER IN-LINE ENGINE
1
2
3
4
5
6
7
8
1-5
3-7
2-6
4-8
8-CYLINDER V-TYPE ENGINE
1-5
3-7
2-6
4-8
1-4
2-3
4-CYLINDER ENGINE
1
2
3
4
1-6
2-5
3-4
6-CYLINDER ENGINE
1
2
3
4
5
6

75.81B

Figure 6-12.—Crankshaft and throw arrangements.

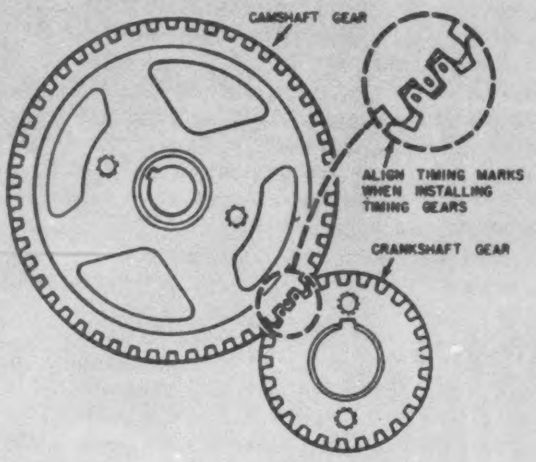
crankshaft must make two revolutions for each power stroke of the piston of a four-stroke cycle engine. In a two-stroke cycle engine, a power stroke occurs during each revolution of the crankshaft. When the piston is at TDC ready to start the power stroke, the throw for that cylinder is also at the top of its travel. As the power is applied to the piston, it is conveyed by the connecting rod to a downward thrust on the throw. This thrust, as it passes from piston to piston, exerts a continuing turning force to the crankshaft.

A piece of rotating machinery usually has a critical speed at which it will vibrate. Thus the thrust of power just described creates a torsional or twisting vibration of the crankshaft. The torsional vibration, which could actually break the crankshaft, is controlled by a vibration damper on the front of the crankshaft. More information concerning crankshafts and vibration dampers is given in *Basic Machines.* It is often desirable to repair crankshafts rather than replace them because they are large and expensive. This will be done at the overhaul shop.

TIMING GEARS AND FLYWHEELS

The crankshaft timing gear of an engine is fastened to the front end of the crankshaft. It turns a camshaft timing gear so that the camshaft is turning in proper relationship to the crankshaft to open and close the valves at the proper time. The gears are keyed to their respective shafts so that they cannot slip. Direct driven timing gears are marked so they can be replaced in the same relative position if removed. (See fig. 6-13.) In some engines, sprockets and chains are used to connect the crankshaft to the camshaft. Besides operating the valve mechanism, the camshaft may have cams or gears that operate the ignition distributor, fuel pump, fuel injector, and lubrication pump.

The flywheel is mounted on the rear end of the crankshaft. It stores energy when the piston delivers thrust to the crankshaft on the power stroke and uses this energy to keep the engine operating when no thrust is being delivered to the crankshaft. The flywheel also helps the crankshaft turn evenly and smoothly by dampening the jerky and uneven movement imparted by the thrust of the pistons. The flywheel is small if the engine has a large number of cylinders, because the consequent overlapping of power impulses results in less need for the energy storing and dampening qualities of the flywheel. Conversely, a 1-cylinder engine would need a relatively large flywheel. The rim of the flywheel has a ring gear that meshes with the starter driving gear that is used for cranking the engine. The rear surface of the flywheel can be machined or ground smooth to act as one of the surfaces of a pressure clutch.



81.69

Figure 6-13.—Timing gears and their markings.

VALVES

Most engines have poppet valves (also called mushroom or tulip valves). The word "poppet" comes from the popping action of the valve; "mushroom" and "tulip" comes from the shape of the valve. Most engines have two valves for each cylinder. The intake valve allows the air (diesel) or air-fuel (gasoline) to enter the cylinder, and the exhaust valve permits the residue of the burning to escape from the cylinder. The intake valves are ordinarily made of chromium-nickel alloy. The exhaust valves are generally made of silichrome alloy because of the extremely high temperatures they must withstand. Sometimes exhaust valves contain sodium in a sealed cavity extending from head to stem. This sodium cools the valves by conducting heat away from them.

WARNING: When sodium-filled engine valves become unserviceable, they should not be discarded to the metal scrap pile. Should the sodium in the valves come in contact with water, the valve may explode. The valves should be appropriately tagged for identification, provisions made for their temporary storage, and they should be shipped to the nearest naval ammunition depot for proper disposal.

Both the intake and the exhaust valves operate against the rims of circular openings (valve ports) in the combustion chambers of the cylinders. These rims are called valve seats (fig. 6-14). The valve and valve seat must make perfect contact. Although some earlier engines were designed with flat contact surface for the valve and valve seat, most are now designed with valve seat angles of 30° to 45° as shown in figure 6-14. This angle helps prevent excessive accumulation of carbon on the contact surface of the seat, a condition which keeps the valve from closing properly. Carbon deposits, incidently, tend to pit the softer metal of the cylinder block and head.

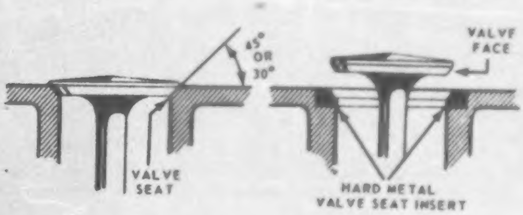
Many engines have replaceable valve seat inserts (fig. 6-15) made of special heat-resistant alloys. These inserts can be used in either cast iron or aluminum blocks or heads. When a valve seat insert is badly worn from grinding or pitting, it must be replaced.

RECONDITIONING VALVES AND VALVE SEATS

Valve reconditioning includes grinding valves and valves seats, adjusting valve tappet clearances, installing new seat inserts, and timing the valves. Together, these operations constitute the valve service necessary for smooth engine performance and maximum power output.

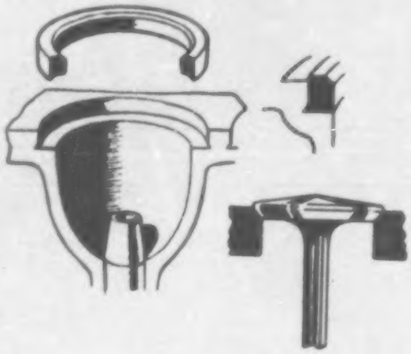
"Grinding valves" is a common expression used around the shop. It is the major, but not the only, operation in reconditioning them. Before valves are ground or refaced on the valve-refacing machine, they must be cleaned. Heavy carbon deposits and excessively burned valves may indicate the need for new rings or valve guides and/or intake valve oil seals. Carbon deposits and burned valves may also indicate improper combustion resulting from poor spark ignition in the gasoline engine or improper fuel injection in the diesel engine.

To recondition valve and valve seats, first take off the cylinder head and remove the carbon from the head and the block. Then remove the valves. Using either a wire brush or a



75.75

Figure 6-14.—Valve head and seat angle.



81.67

Figure 6-15.—Valve seat insert.

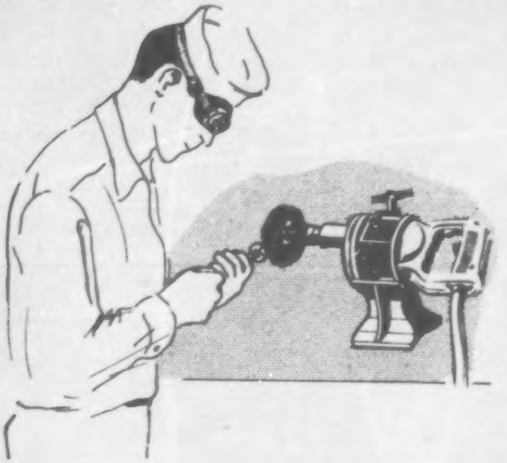
wire buffing wheel (fig. 6-16), clean the carbon off the valves. When using the buffing wheel, wear goggles so that particles of wire and other foreign matter will not fly into your eyes. Clean the valve stems with fine abrasive cloth.

Be careful not to interchange the valves and the valve parts; each valve, with its own spring, retainer, and lock must be replaced in the same valve port from which it was removed. To eliminate any confusion, devise some system of marking the valves to identify them with the cylinders from which they were taken.

After cleaning the valves and checking them for wear, clamp the valve stem in the chuck of the valve-refacing machine. Be sure that the grinding angle index is set to the angle of the valve head that is to be ground. Follow the operating instructions of the manufacturer of the refacing machine, together with those of your supervisor, while becoming familiar with the details of grinding.

If the tip ends of the valve stems are rough, smooth them by grinding lightly with a special attachment furnished with the valve-refacing machine.

Before the valve seats are serviced, the valve guides must be serviced and replaced if necessary.



81.68

Figure 6-16.—Cleaning a valve with a wire buffing wheel.

VALVE GUIDE SERVICE

Servicing of valve guides is an important, but often neglected, part of a valve job. The guide must be clean and in good condition before a good valve seat can be made. Wear of valve guides is generally the only trouble that will be encountered.

There are several satisfactory methods of checking for valve guide wear. One procedure includes the use of a dial indicator. With the valve in place, turn the engine so that the valve is moved off its seat. Install the dial indicator on the block with the indicating button touching the edge of the valve head. Move the valve sideways to determine the amount of wear. Another checking procedure involves the use of a small hole gage to measure the inside of the guide and a micrometer to measure the valve stem; the difference in the readings will be the clearance. Check the manufacturer's manual for the allowable maximum clearance. When the maximum clearance is exceeded, the valve guide will need further servicing before proceeding with the valve job.

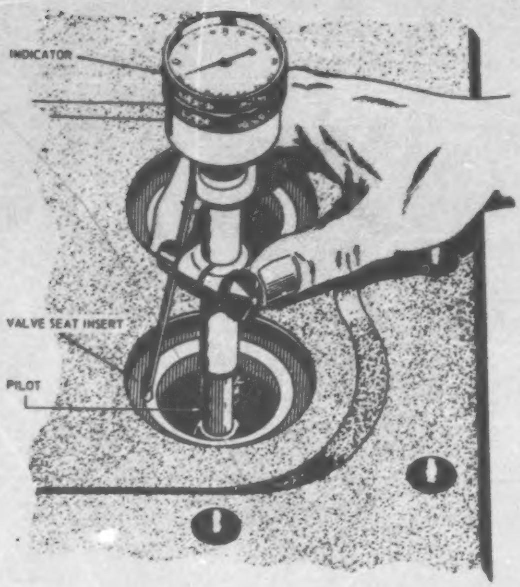
Servicing procedures will depend on whether the guide is of the integral or the replaceable type. If of the integral type, it must be reamed to a larger size and a valve with an oversize stem installed; but if it is of the replaceable type, it should be removed and a new guide installed.

Valve guides should be removed and replaced with special drivers. When working on a valve-in-head engine, use an arbor press to remove and replace valve guides.

After the valve guides are serviced and the valve seats are ground, check the concentricity of the two with a valve seat dial indicator (fig. 6-17). Any irregularity in the seat will register on this dial.

Valve Seat Service

If a replaceable seat is badly worn or ground down, replace it with a new one. Remove the old seat either with a puller or by drilling it on two opposite sides and then breaking it in halves with a hammer and chisel. New inserts should be chilled in dry ice for about 15 minutes to shrink them so that they can be easily driven into place.



75.73
Figure 6-17.–Using a valve seat dial gage.

In some cases the valve seats are not replaceable, so they must be ground. Equipment that is used for servicing valve seats is discussed in chapter 2 of this training manual. Be sure you know how to operate the kind of equipment that is in your shop. Study the manufacturer's manual if necessary.

Select the proper size pilot for the valve guide and insert and lock it into the guide. Wipe the valve seat free of carbon dust and oil. Then with a clean oily rag, apply a thin film of oil to the pilot shaft.

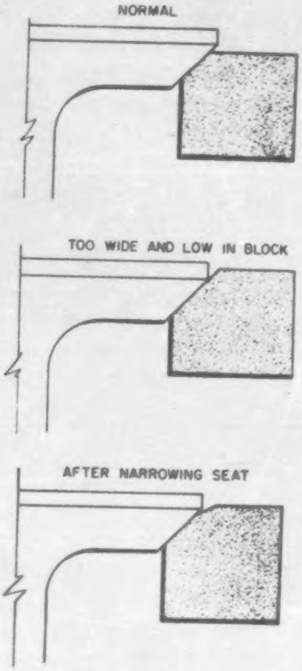
Use two or more stone sleeves to facilitate seat grinding if the engine block has both soft and hard seats, or if a high polish "finish grind" is desired.

One sleeve may carry a soft seat stone, another the hard seat stone, a third sleeve the finishing stone, and possibly a fourth sleeve may carry a 20° narrowing stone. This eliminates the delay that would be involved in changing stones when different grinding conditions are encountered. Make sure the stones are dressed at the proper angle in accordance with the engine manufacturer's specifications.

Only a few seconds are required to recondition the average valve seat. Check the progress of the grinding operation often, and do not remove any more material than is necessary to obtain a good seat.

Although recommended, it is usually not necessary to lap the contact surfaces of the valve and valve seat after they have been ground. Always check your work by testing one or two of the valves. This check can be made by spreading a thin coat of Prussian blue on the valve face or by putting lead pencil marks on the valve seat. If, when turning a valve on its seat, an even deposit of the coloring is seen on the valve seat, or the pencil lines are removed, the seating is perfect.

Figure 6-18 shows a normal valve seating; this will vary according to the manufacturer's specification. When a great deal of grinding is



227.30
Figure 6-18.–Valve seat.

necessary on a badly burned or worn seat, a condition such as that shown in figure 6-18 will occur. When this occurs, narrow the seat by using a 20° narrowing stone. Figure 6-18 shows a seat that has had metal removed by narrowing. Grinding with the narrowing stone usually requires only a few seconds. Check often while grinding so that too much metal will not be removed.

Checking Valve Springs

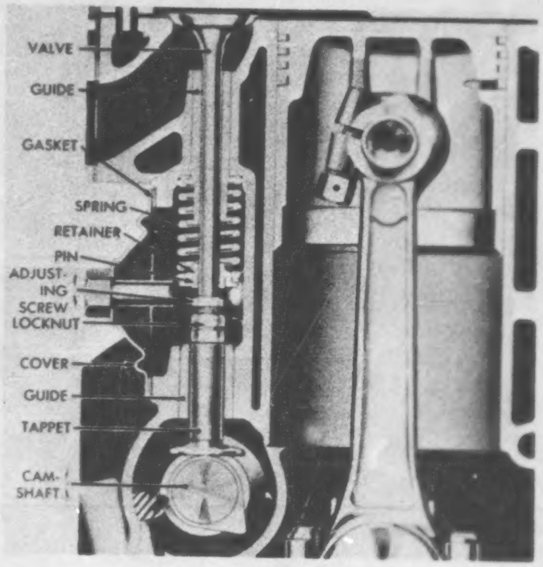
While working with valves, notice that some of them have more than one spring. These additional springs are coiled to offset a tendency of the valve to vibrate at high engine speeds. They also insure proper valve seating and provide a safety factor in case one spring should break.

Test valve springs for uniformity and strength. For an accurate test, use a valve spring tester when one is available. If a valve spring tester is not available, place used springs on a level surface beside a pair of new springs. Use any straightedge to determine irregularities in height. Replace worn out springs with new ones. Unequal or cocked valve springs will undo, in the assembled job, all the precision that has been put into the grinding operation.

VALVE OPERATING MECHANISM

Because the valves operate at different times, separate operating mechanisms must be provided for each valve. Valves are held closed by heavy springs and by compression in the combustion chamber. The valve operating mechanism (fig. 6-19) overcomes the spring pressure and opens the valves at the proper time. This mechanism includes the camshaft, camshaft followers (tappets), push rods, and rocker arms. Chapter 13 of *Basic Machines,* NAVEDTRA 10624 (Series), contains the description and operation of these parts of the valve operating mechanism.

Proper and uniform valve adjustments are required for a smooth running engine. Unless the clearance between valve stems and rocker arms or valve lifters is adjusted in accordance with the manufacturer's specifications, the valves will not open or close at the proper time and engine performance will be affected. Too great a clearance will cause the valves to open late. Valves adjusted with too little clearance will overheat and warp. Warped valves cannot seat properly and will permit the escaping combustion flame to burn both the valve and valve seat. Too great a clearance may also prevent a valve from opening far enough and long enough to admit a full charge of air or fuel mixture (either diesel or gasoline engine), or it will prevent the escape of some exhaust gases from the cylinder. A reduced charge in the cylinder obviously results in engine power loss. Exhaust gases that remain in the cylinder take up space; and when combined with the incoming charge, they reduce the effectiveness of the mixture.



227.31

Figure 6-19.—Valve operating mechanism for valves in block type engine.

To adjust the valves, insert a feeler gage between the tappet and valve stem when the valves are in the block or between the rocker arm and the valve stem for overhead valves. The rocker arm or tappet adjusting screw can be turned to widen or close the gap. Consult the manufacturer's specifications for the proper clearance.

VALVE ADJUSTING

When an engine has been reassembled after reconditioning the valves, make sure the adjusting screws are backed off before rotating the engine. A valve that is too tight could strike the piston and damage the piston, the valve, or both. Adjust the valves in accordance with the manufacturer's specifications, following recommended procedure.

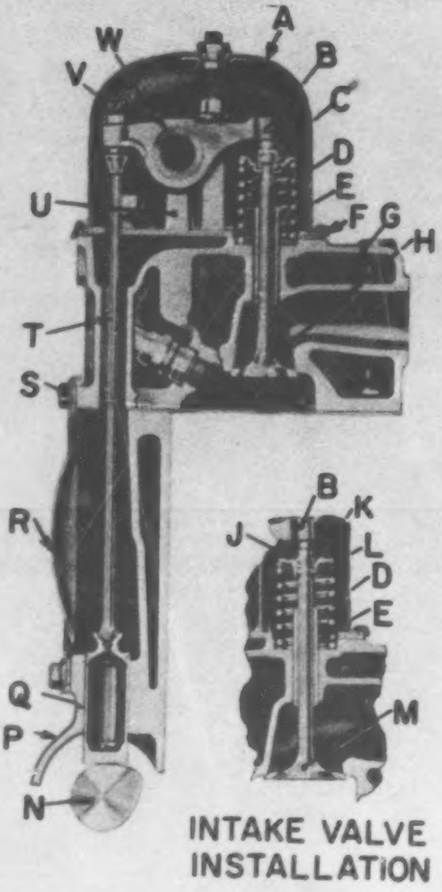
On any engine where valve adjustments have been made, be sure the adjustment locks are tight, and that the valve mechanism covers and gaskets are in place and securely fastened to prevent oil leaks.

ADJUSTING OVERHEAD VALVES

Most overhead valves (fig. 6-20) are adjusted "hot"; that is, valve clearance recommendations are given for an engine at operating temperatures. Before valve adjustments can be properly effected, the engine must be run and brought up to normal operating temperature.

ADJUSTING VALVES IN BLOCK

Valves within the block are generally adjusted "cold", that is, recommended valve clearances are given for a cold engine. These valves have mechanisms very much like overhead valves and are adjusted by removing side plates usually found beneath the intake manifold on the side of the engine block. Since this engine must be stopped to adjust the valves, the piston in the cylinder to be adjusted must be on top dead center of the compression stroke. This can be determined by watching the valves of the piston that is paired with the one that is being set. As the cylinder that is being positioned is coming up on the compression stroke, the paired cylinder will be coming up on the exhaust stroke. Therefore, an exhaust valve will be open. Just as the exhaust valve closes and the intake valve begins to open, the cylinder that is to be set will be on top dead center of the compression stroke and the two valves can be set. Once number one cylinder is positioned, follow through according to the firing order of the engine, as this makes the job much easier and faster. The above procedure may also be used when adjusting valves on overhead valve engines.



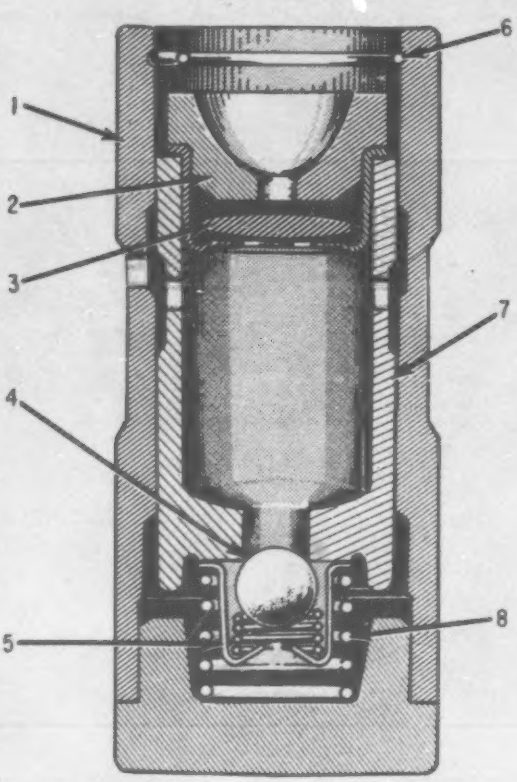
A–CYLINDER HEAD COVER
B–ROCKER ARM
C–ROTATOR CAP
D–VALVE SPRING
E–VALVE GUIDE
F–COVER GASKET
G–CYLINDER HEAD
H–EXHAUST VALVE
J–VALVE SPRING CAP
K–INTAKE VALVE KEY
L–SEAL
M–INTAKE VALVE
N–CAMSHAFT
P–CRANKCASE
Q–VALVE TAPPET
R–PUSH ROD COVER
S–GASKET
T–PUSH ROD
U–ROCKER ARM SHAFT BRACKET
V–ADJUSTING SCREW
W–ROCKER ARM SHAFT

81.85

Figure 6-20.–Valve operating mechanism for an overhead valve engine.

HYDRAULICALLY OPERATED VALVE ADJUSTMENT

On engines equipped with hydraulic valve lifters (fig. 6-21) it is not generally necessary to adjust the valves periodically. They operate with zero clearance. (See fig. 6-22). The engine lubrication system supplies a flow of oil to the lifters at all times. These hydraulic lifters operate at zero clearance and compensate for changes in engine temperature, adapt automatically for minor wear at various points, and thus provide ideal valve timing.



1. Lifter body.
2. Push rod seat.
3. Inertia valve.
4. Check ball.
5. Ball retainer.
6. Push rod seat retainer.
7. Plunger.
8. Plunger spring.

227.32

Figure 6-21.—Hydraulic valve lifter.

If for any reason the valve mechanism must be repaired, an initial adjustment must be made after reassembling the job. Nearly every manufacturer will have a different procedure for making this adjustment. Check the manufacturer's serivice guide for the engine concerned.

HYDRAULIC VALVE LIFTER SERVICE

Hydraulic valve lifters are comparatively simple in design. Servicing of the lifters requires only that care and cleanliness be exercised in the handling of parts.

The first indication of a faulty lifter is that it will start making a "clicking" noise. The listening rod or an engine stethoscope is helpful in locating a noisy valve lifter by placing one end of the tool against the particular part of the engine and the other part to your ear. You should move the instrument around the engine until you have narrowed the noise down to a certain area. In an emergency or normal situation a long screwdriver or a piece of garden hose may be used. Be careful of the moving fan belt and fan blade.

Usually, where noise exists in one or more of the valve lifters, all lifter units should be removed, cleaned in a solvent, reassembled, and reinstalled in the engine. If dirt, carbon, or the like, exists in one unit, it more than likely is in all of them; and it will only be a matter of time before the other lifter units will give trouble.

Parts of hydraulic valve lifters are not interchangeable. Should one part become damaged, it is necessary to replace the whole unit. The plunger must be free to move in the lifter body. A simple test for this is to be sure that the plunger will drop of its own weight in the body.

Cylinder Head

The cylinder head provides the combustion chambers for the engine cylinders. It is built to conform to the arrangement of the valves: L-head, I-head, or other.

In the water-cooled engine the cylinder head (fig. 6-23) is bolted to the top of the cylinder

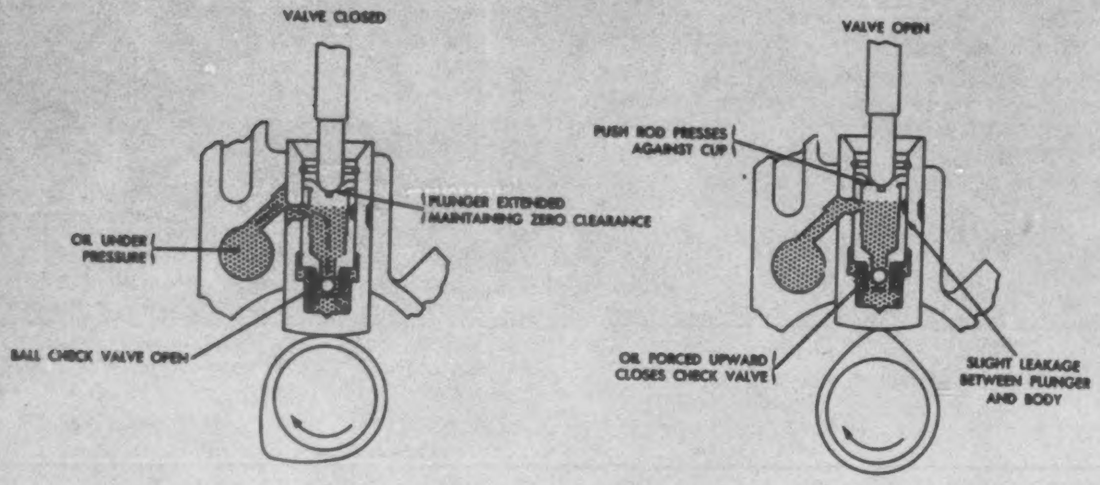

VALVE CLOSED
PLUNGER EXTENDED
MAINTAINING ZERO CLEARANCE
OIL UNDER
PRESSURE
BALL CHECK VALVE OPEN
VALVE OPEN
PUSH ROD PRESSES
AGAINST CUP
OIL FORCED UPWARD
CLOSES CHECK VALVE
SLIGHT LEAKAGE
BETWEEN PLUNGER
AND BODY

Figure 6-22.—Operation of a hydraulic valve lifter. 227.33

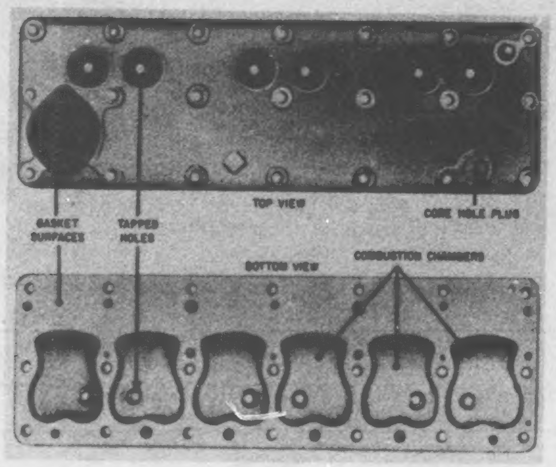

TOP VIEW
CORE HOLE PLUG
GASKET
SURFACES
TAPPED
HOLES
BOTTOM VIEW
COMBUSTION CHAMBERS

Figure 6-23.—Cylinder head for L-head engine. 81.50

block to close the upper end of the cylinders. It contains passages, matching those of the cylinder block, which allow the cooling water to circulate in the head. The head also helps retain compression in the cylinders. In the gasoline engine there are tapped holes in the cylinder head which lead into the combustion chamber. The spark plugs are inserted into these tapped holes.

In the diesel engine the cylinder head may be cast in a single unit, or may be cast for a single cylinder or two or more cylinders. Separated head sections (usually covering 1, 2, or 3 cylinders in large engines) are easy to handle and can be readily removed.

The L-head type of cylinder head shown in figure 6-23 is a comparatively simple casting. It contains water jackets for cooling, and openings for spark plugs. Pockets into which the valves operate are also provided. Each pocket serves as a part of the combustion chamber. The fuel-air mixture is compressed in the pocket as the piston reaches the end of the compression stroke. Note that the pockets have a rather complex curved surface. This shape has been carefully designed so that the fuel-air mixture, in being compressed, will be subjected to violent turbulence. This turbulence assures uniform mixing of the fuel and air, thus improving the combustion process.

The I-head (overhead-valve) type of cylinder head contains not only water jackets for cooling spark-plug openings, and valve and combustion-chamber pockets, but it also contains and supports the valves and valve-operating mechanisms. In this type of cylinder head, the water jackets must be large enough to cool not only the top of the combustion chamber but also the valve seats, valves, and valve-operating mechanisms.

The head is inspected periodically for cracks. The crack will usually show up by leaking water, water in the oil or vice versa, or combustion chamber blowby. First inspect the head gasket, as it will normally be at fault. When replacing a cylinder head, the bolts must be tightened according to the manufacturer's specifications, with a torque wrench.

The cylinder head of an air-cooled engine is finned to help dissipate the heat caused by combustion. It does not usually contain the valves or their operating mechanism, as these parts are a part of the cylinder assembly. One way to detect a cracked head on an air-cooled engine is by compression blowby.

OIL PANS AND COVERS

The oil pan is situated at the bottom of the block or crankcase if they are separate. It is made of pressed or cast steel and holds the oil supply for the engine. The crankshaft, camshaft, connecting rods, and the underside of the pistons can be inspected by removing the oil pan. The oil pan is usually designed so that the oil drains to the rear when the engine is level, thereby allowing the oil pump to pick up the oil and recirculate it. This low part has a plug for draining the oil. The pan is bolted to the block or crankcase around the rim, and an oil pan gasket prevents oil leakage. To remove the oil pan, all the studs holding it should be removed. It should then drop away from the block or crankcase. A new gasket should always be used when replacing an oil pan. Be sure the surfaces with which the gasket comes in contact are clean. The studs should be tightened to the torque specified for that engine when replacing the oil pan.

Figures 6-19 and 6-20 show the valve and valve operating mechanism covers of a liquid cooled gasoline engine. These covers are bolted on and are sealed by gaskets. The same instructions for removal and replacing the oil pan apply to the removal and replacing of covers.

COOLING SYSTEM

The purpose of the cooling system is to keep the engine operating at its most efficient temperature. Cylinder-wall temperature must not increase beyond about 400° or 500° F. Temperatures higher than this will cause the lubricating oil film to break down and lose its lubricating properties. However, it is desirable to operate the engine at temperatures as close to the limits imposed by oil properties as possible.

Since the engine is quite inefficient when cold, the cooling system includes devices that prevent normal cooling action during engine warmup. These devices allow the working parts of the engine to reach operating temperature quickly and shorten the inefficient cold-operating time. Then, when the engine reaches operating temperatures, the cooling system begins to function. Thus, the cooling system cools rapidly when the engine is hot, and it cools slowly or not at all when the engine is warming up or cold.

Two general types of cooling systems are used–air cooling and liquid cooling.

AIR COOLED ENGINES

An air cooling system does not employ a liquid coolant, so it is often assumed that air alone acts as the cooling medium. However, this is not true, since the fuel and lubrication systems also help in cooling the engine. The lubrication system for an air cooled engine often includes an oil cooler which circulates the oil between the engine and the cooler, removing heat from the engine as it does so. Some cooling also results from the fuel contacting metal parts prior to combustion.

There are several physical characteristics peculiar to the air cooled engine; the cylinder head and cylinder are finned for strength and for adequate cooling. In most engines, air deflectors, shrouds, or baffles direct the flow of air to the cylinders. Cooling fans are used to increase the volume of air circulating around the cylinders; this also increases the speed of the air passing the cylinders.

Maintenance of the cooling system of air-cooled engines consists largely of keeping the parts clean to permit rapid transfer and dissipation of heat, and making sure that nothing interferes with the proper flow of air through the cooling system.

To accomplish this, keep the baffles, fins, shrouds, and fans free of dirt, grease, and other foreign matter. Periodically inspect and tighten the shrouds, baffles, and deflectors. Replace or straighten broken or bent parts.

LIQUID COOLING SYSTEM

Nearly all multicylinder engines used in automotive, construction, and weight handling equipment use a liquid cooling system. Any liquid used in this type of system is called a coolant.

In most liquid cooled engines, waste heat is removed by the coolant circulating through hollow passages surrounding the hottest parts of the engine. Heat first flows into the coolant while the coolant is being pumped through the passages of the cylinder block and up into the cylinder head. The coolant then moves on through similar passages in the head, picks up more heat as it circulates, and finally leaves the engine through an outlet at the top.

After leaving the engine, the coolant passes through an upper hose connection and carries the heat into a radiator. As the coolant flows down through the radiator, the heat is removed by a stream of air forced through the radiator, by the action of a fan only in stationary engines, and by both the fan and forward motion in vehicles.

From the bottom of the radiator, the coolant flows through a lower hose connection to the pump where it is again forced into the cylinder block and repeats the cooling cycle, removing more heat from the engine and carrying the heat into the radiator.

Water Jacket

The water passages in the cylinder block and cylinder head form the engine water jacket. (See fig. 6-24.) In the cylinder block, the water jacket completely surrounds all cylinders along their full length. Within the jacket, narrow passages are provided between the cylinders for coolant circulation around them. In addition, water passages are provided around the valve seats and other hot parts of the cylinder block. In the cylinder head, the water jacket covers the combustion chambers at the top of the cylinders and contains passages around the valve seats when the valves are located in the head.

The passages of the water jacket are designed to control circulation of coolant and to provide proper cooling throughout the engine.

Water Pump

Water pumps are usually located on the front or side of the engine block. They receive coolant from the bottom of the radiator and force it through the water jacket into the top radiator tank.

The water pump (fig. 6-25) is a centrifugal type pump, having an impeller with vanes which

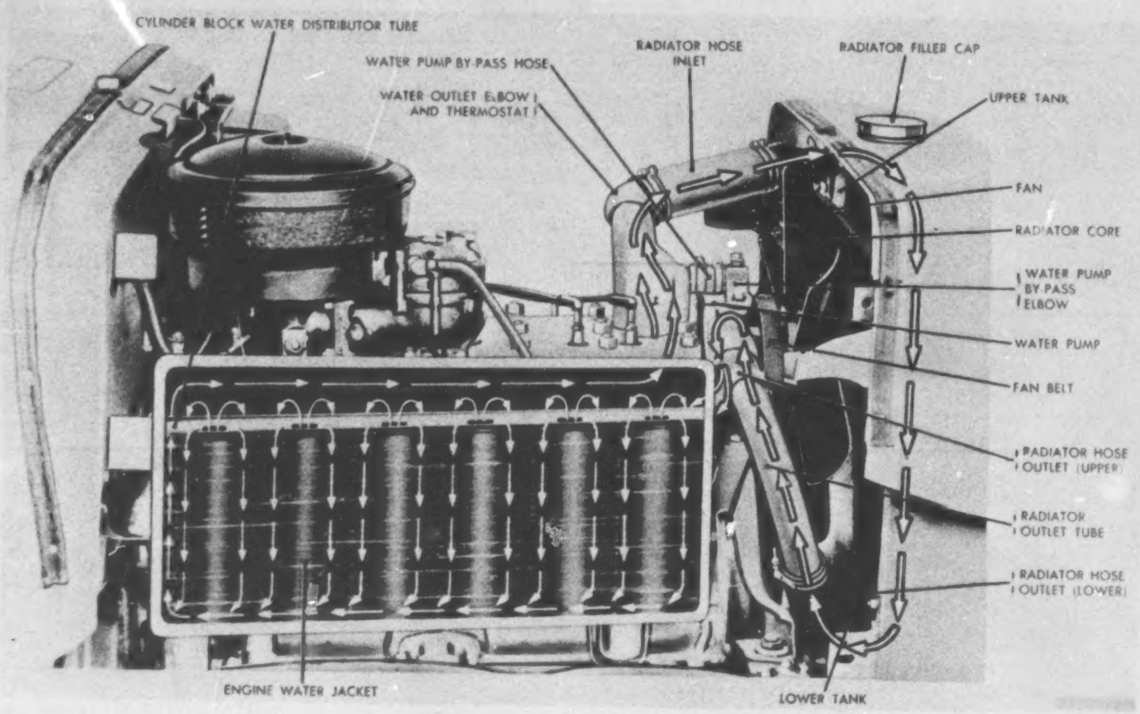

CYLINDER BLOCK WATER DISTRIBUTOR TUBE
WATER PUMP BY-PASS HOSE
WATER OUTLET ELBOW AND THERMOSTAT
RADIATOR HOSE INLET
RADIATOR FILLER CAP
UPPER TANK
FAN
RADIATOR CORE
WATER PUMP BY-PASS ELBOW
WATER PUMP
FAN BELT
RADIATOR HOSE OUTLET (UPPER)
RADIATOR OUTLET TUBE
RADIATOR HOSE OUTLET (LOWER)
ENGINE WATER JACKET
LOWER TANK

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Figure 6-24.—Water cooling system showing water jacket.

force the coolant outward as the impeller rotates. The impeller is located in a pump housing and is mounted on a shaft which runs on one or more bearings. The shaft is driven by the engine through a belt or a shaft. The fact that the impeller is submerged in the coolant, but is driven from outside of the cooling system, creates the problem of sealing the impeller shaft against leakage.

For different cooling systems, pumps vary considerably in construction of seals, bearings, mounting, and drive.

It is usually easier to remove the water pump if the radiator has first been removed. Loosen the fan belt and remove the studs holding the water pump to the block and cylinder head. When replacing the water pump, use a new gasket.

Fan and Shroud

The engine fan is usually mounted on the end of the water pump shaft and is driven by the same belt that drives the pump. The fan provides a powerful draft of air through the radiator. Some applications are equipped with a fan shroud that improves fan performance. This assures that all the air pulled back by the fan passes through the radiator.

Fan blades are often spaced at unequal distances around the fan hub to lessen vibration and noise. They are often curled at the tip to increase their ability to move air. Except for differences in location around the hub, it may be assumed that all blades should have the same pitch and angularity.

Bent fan blades are very common and result in noise, vibration and excess wear on the fan

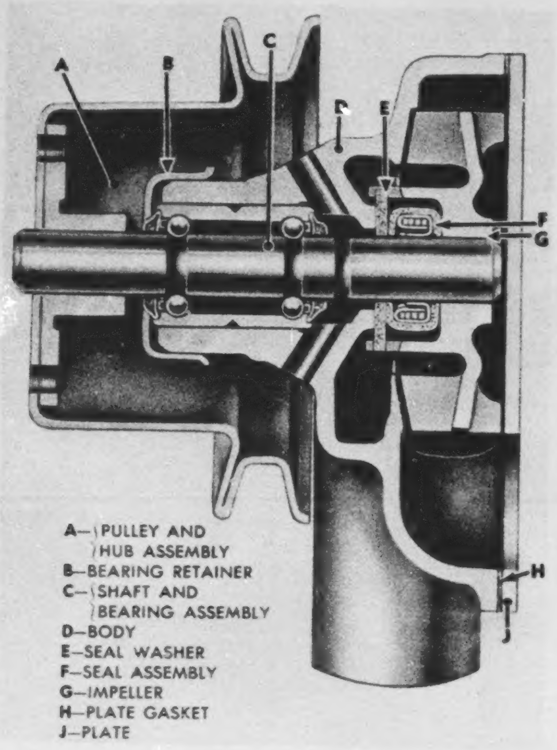

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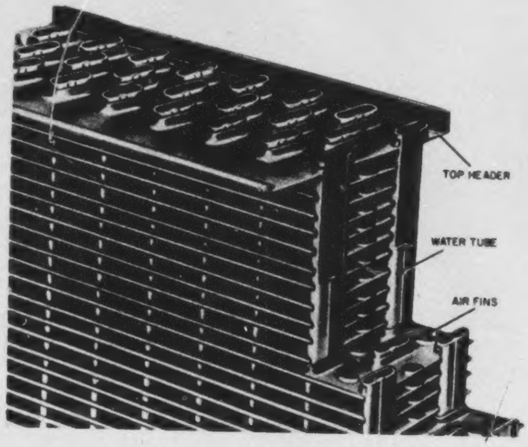
Figure 6-25.—Water pump.



81.102

Figure 6-26.—Tubular radiator core construction.

shaft, and inefficiency. Make it a practice to visually inspect the fan blades, pulleys, and drive belts at every preventive maintenance inspection.

Cooling fans absorb a considerable amount of the engine power, particularly at high speeds. Thermostatically controlled friction devices are being used on some installations to slow down or cut out the fan at high engine speeds or when the engine is cold.

Radiator

The usual radiator assembly consists of a radiator core with a top tank and a bottom tank. The top, or inlet tank, contains an outside pipe called the radiator inlet and usually has a coolant baffle inside and above, or at the inlet opening. The radiator filler neck is generally attached to the upper part of the top tank and has an outlet to the overflow pipe. The bottom tank also has an opening which is called the radiator outlet.

Practically all cooling systems have tubular radiator cores (fig. 6-26) which consist of a large number of vertical tubes and many horizontal air fins around the tubes. Water passages in the tubes are usually very narrow, and the tube itself is made of a very thin metal.

Through the water tubes, the flow of coolant is divided into many small streams which cause a small amount of cooling liquid to be exposed to a comparatively large cooling surface. This results in rapid flow of heat from the coolant to the tubes and air fins. Heat is carried away from the tubes and fins by the air moving through the core.

To remove the radiator, first remove the inlet and outlet radiator hoses. Next remove the radiator cover, if it is fitted with one, and remove the bolts holding the radiator to its frame. The radiator can now be lifted out. Be careful not to puncture the core.

Connections must be provided to carry the water from the engine water jacket to the radiator, and from the radiator back to the engine. Vibration and movement between the radiator and the engine would cause breakage of metal pipe. For this reason, flexible hose is used for radiator connections. Sometimes pieces of pipe are placed between sections of hose where the connections are long.

Radiator Pressure Cap

The radiator pressure cap (fig. 6-27) is used on nearly all modern engines. The pressure cap closes off the overflow pipe and prevents loss of coolant during normal operation. It also allows a certain amount of pressure to develop within the cooling system. The pressure raises the boiling point of the coolant and permits the engine to operate at high temperatures without loss of coolant from boiling.

The pressure cap contains two spring-loaded valves. The larger valve is called the pressure valve, and the smaller one is called the vacuum valve. A shoulder in the radiator filler neck provides a seat for the bottom of the cap assembly, and a gasket on this seat prevents leakage between the cap and the filler neck.

The pressure valve acts as a safety valve to relieve extra pressure within the system. The cooling system may be designed to operate at various pressures—4 to 17 psi, depending on the manufacturer's specifications. The pressure valve in the cap is preset by the manufacturer. When replacing a pressure cap, make sure to use a cap with the proper pressure setting which is usually marked on the top surface of the cap.

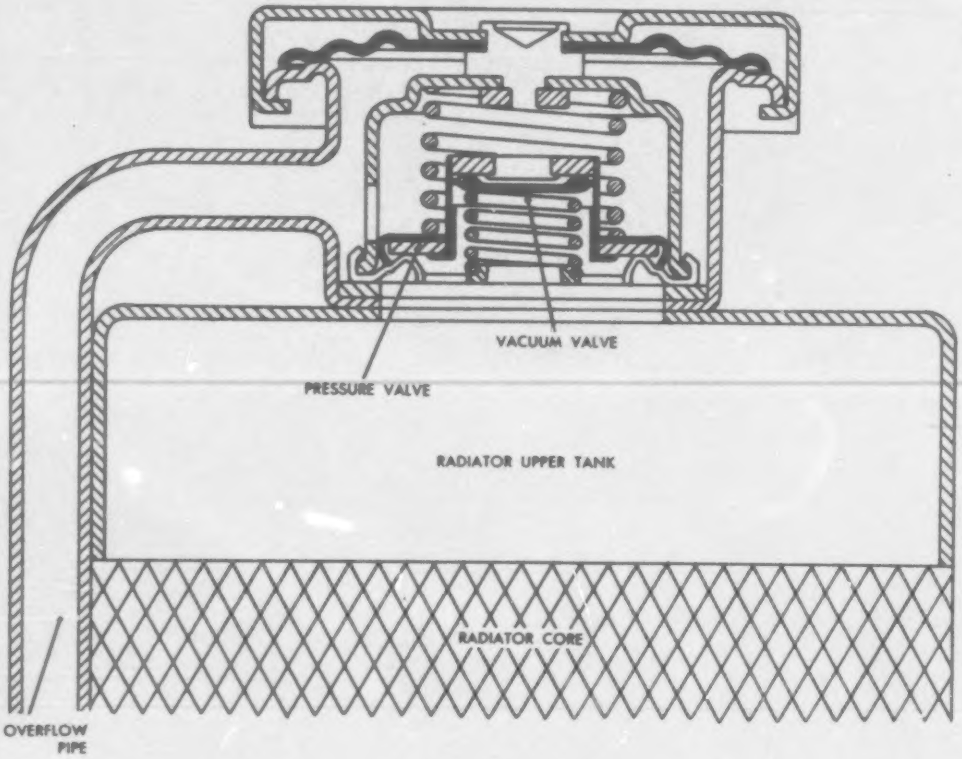


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Figure 6-27.—Pressure radiator cap.

The vacuum valve opens only when the pressure within the cooling system drops below the outside air pressure as the engine cools. This automatic action of the vacuum valve prevents collapse of hose and other thin-walled parts of the cooling system.

Thermostat

The function of the thermostat (fig. 6-28) is to automatically control the amount of heat removed from the engine for different operating conditions and air temperatures.

The thermostat is a heat operated unit which controls a valve between the water jacket and the radiator. Attached to the valve is a flexible metal bellows, which is expansible and contains a volatile liquid or gas which creates a pressure when heated and opens the thermostatic valve. As the engine warms up, the valve opens slowly and allows the water to circulate. It is fully open when the engine reaches operating temperature. When the engine is cold, the valve stays closed and shuts off practically all circulation to the radiator. Most cooling systems equipped with thermostats have a bypass arrangement to allow a little water circulation when the thermostat is closed.

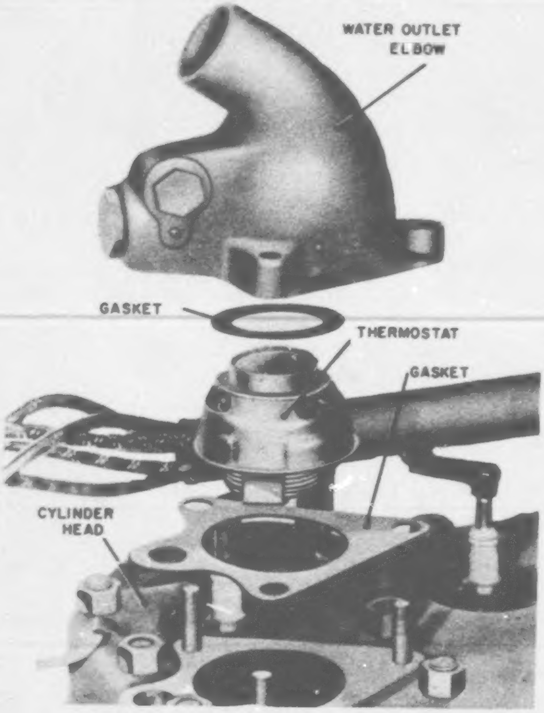

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Figure 6-28.—Thermostat.

To replace a thermostat, the hose should be removed from the water outlet elbow (fig. 6-28), the elbow unbolted from the cylinder head, and the thermostat removed. When a thermostat is installed, use new gaskets and reverse the removing procedure.

The operation of a closed bellows type thermostat is shown in figure 6-29. In actual operation, the valve will move frequently to regulate the flow of water to the radiator in accordance with the variations in heat output of the engine. Other types of thermostats may be operated by a bimetallic coil which expands when heated and opens the valve. As the coil cools, it contracts and closes the valve.

Although a thermostat is designed to open at a specific temperature, most thermostats vary a few degrees in the temperature at which they begin to open. In addition they may require a temperature from 20° to 25° F higher before they are fully open. For instance, a thermostat designed to open at 150° F might begin to open at any temperature between 146° and 154° F inclusive. This same thermostat should be fully open at 170° to 175° F.

Some vehicles are equipped with air inlet screens or shutters. They are used in cold weather to help warm up the engine. They have no direct connection with the cooling system and are primarily for protection. However, they may be used to supplement the action of the thermostat, and they are operated either by hand or automatically by a thermostatic device. The shutters restrict the flow of cool air through the radiator when the coolant is below a predetermined temperature.

To replace the shutter, unbolt the mounting brackets, disconnect the control cable or rod, and remove the shutter. A new or repaired one can be installed by reversing this process.

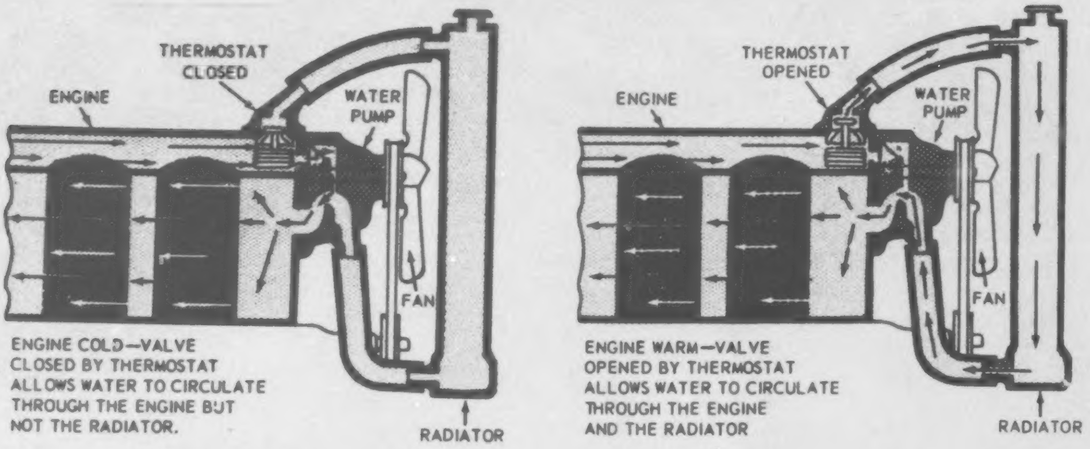
THERMOSTAT CLOSED
ENGINE
WATER PUMP
FAN
ENGINE COLD—VALVE CLOSED BY THERMOSTAT ALLOWS WATER TO CIRCULATE THROUGH THE ENGINE BUT NOT THE RADIATOR.
RADIATOR
THERMOSTAT OPENED
ENGINE
WATER PUMP
FAN
ENGINE WARM—VALVE OPENED BY THERMOSTAT ALLOWS WATER TO CIRCULATE THROUGH THE ENGINE AND THE RADIATOR
RADIATOR

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Figure 6-29.—Diagram of a thermostat in operation.

Temperature Gage

The engine temperature gage is made up of two principal parts–the gage unit mounted on the instrument panel, and the engine thermal unit. When operated on the principle of the Bourdon tube, the temperature gage is actuated by pressure conducted to it from a bulb, which is screwed into the water jacket of the engine. The heat of the water vaporizes the liquid in the bulb, and the vapors flow through a capillary, which is a very small tube connecting the bulb to the gage. The greater the heat, the more vapor given off; the greater the pressure, the higher the temperature indicated on the gage.

When installing the temperature gage or repairing other parts of the engine, be careful not to kink the tube connecting the two units. Although it looks like an ordinary wire, this tube contains the fluid which transmits temperature readings to the gage unit on the instrument panel. A damaged temperature gage must be replaced as a whole unit and cannot be repaired in the shop.

Some vehicles are equipped with an electric temperature gage (fig. 6-30). The operation of this instrument is similar to the balancing coil type oil pressure indicator. The higher the temperature, the greater the current passing through the coils to the indicating unit, so that the armature to which the indicating needle is attached is attracted by an increased magnetic field, which in turn agitates the needle to register the engine temperature.

Antifreeze Solutions

A vehicle operated in temperatures below 32° F requires an antifreeze solution in its cooling system. Without this solution, the water in the cooling system freezes and sometimes results in a cracked cylinder, water jacket, cylinder head, and radiator core.

A good antifreeze solution mixes readily with water. However, once it is mixed with water, it tends to penetrate openings and connections more readily than water. Upon the first filling of antifreeze in the winter, and periodically thereafter, hose connections should be checked for tightness to insure that there are no leaks. A good antifreeze is not subject to rapid evaporation, nor does it corrode or rust the cooling system. Most antifreeze compounds contain a rust and corrosion inhibitor. Without an inhibitor in the solution, rust and corrosion clog radiators and cause water cooled engines to overheat.

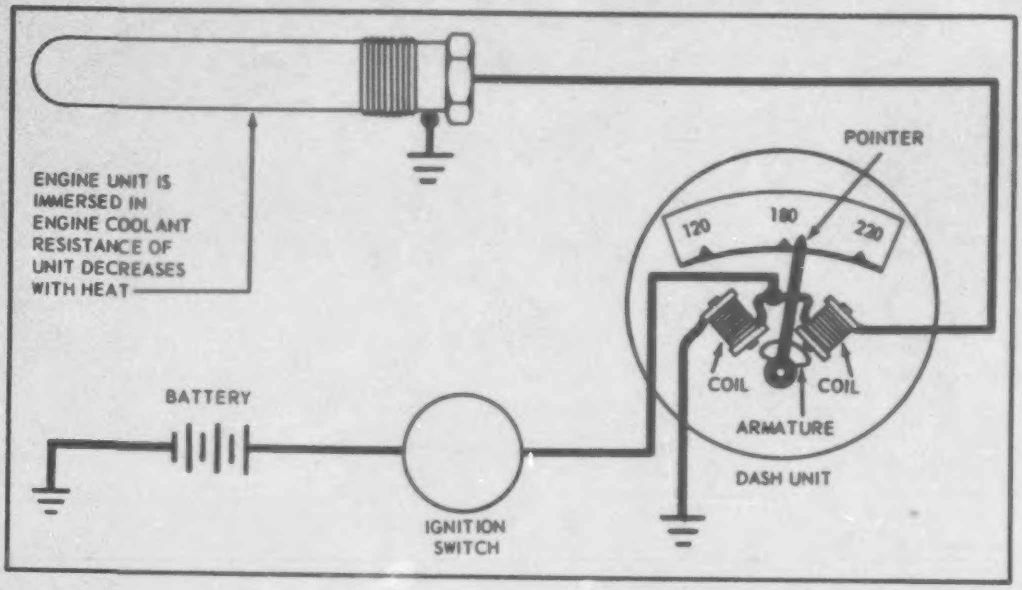

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Figure 6-30.—Circuit diagram of an electric temperature gage.

All antifreeze solutions require periodic checks and must be renewed when tests show that they will not give the required protection against freezing.

Hydrometers are used for testing antifreeze solutions. They usually come with instructions for their use. Their principle of operation is based on the fact that the specific gravity of the solution in the cooling system varies with the temperature at which the solution freezes. Tests are made by drawing a sample of the solution from the radiator with the hydrometer suction bulb. The temperature of the solution is matched with the specific gravity, and a conversion table on the hydrometer indicates the temperature at which the solution will freeze.

Antifreeze solutions, even the so-called permanent types, are not recommended for use beyond one season; furthermore it is recommended that different types not be mixed. Usually when one type has been mixed with another, there is no way of knowing the temperature at which the mixed solutions will freeze. Another danger is that their ingredients sometimes react chemically and cause a corrosion in the cooling system and a foaming that forces quantities of the liquid from the radiator.

Service and Maintenance of Cooling System

How often the cooling system should be flushed and cleaned depends on the existing instructions. It should be done at least twice a year, and it may have to be done at each preventive maintenance inspection. It is necessary to prevent excessive accumulations of rust and other corrosive deposits, which in time could damage the radiator passages.

Begin the flushing procedure by opening the drain cocks (fig. 6-31) and allowing the water to flow out. Refill the system with new water, to which an approved cleaning compound has been added. The various types of cleaning compound available for loosening rust and scale in a radiator should be used only in accordance with

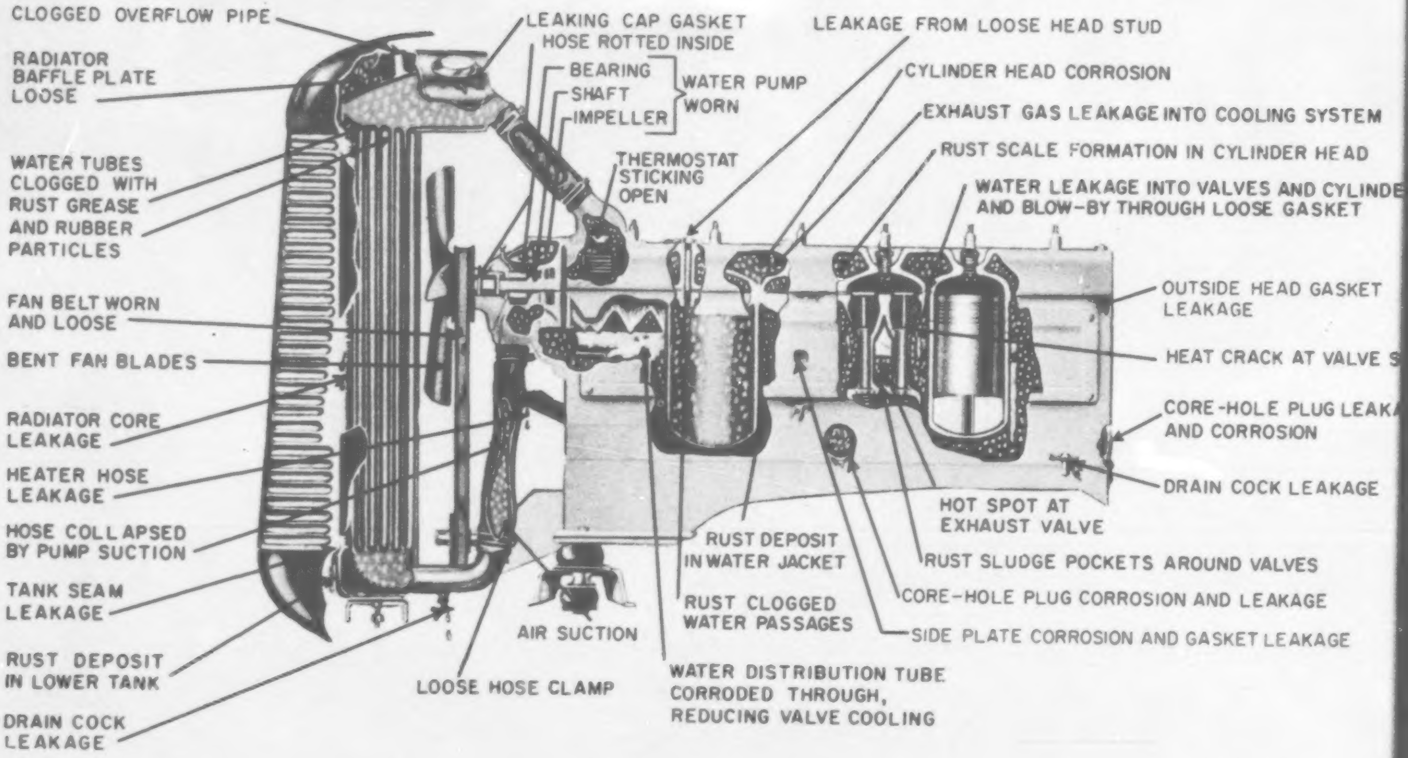
CLOGGED OVERFLOW PIPE
RADIATOR BAFFLE PLATE LOOSE
WATER TUBES CLOGGED WITH RUST GREASE AND RUBBER PARTICLES
FAN BELT WORN AND LOOSE
BENT FAN BLADES
RADIATOR CORE LEAKAGE
HEATER HOSE LEAKAGE
HOSE COLLAPSED BY PUMP SUCTION
TANK SEAM LEAKAGE
RUST DEPOSIT IN LOWER TANK
DRAIN COCK LEAKAGE
LEAKING CAP GASKET
HOSE ROTTED INSIDE
BEARING
SHAFT
IMPELLER
WATER PUMP WORN
THERMOSTAT STICKING OPEN
AIR SUCTION
LOOSE HOSE CLAMP
LEAKAGE FROM LOOSE HEAD STUD
CYLINDER HEAD CORROSION
EXHAUST GAS LEAKAGE INTO COOLING SYSTEM
RUST SCALE FORMATION IN CYLINDER HEAD
WATER LEAKAGE INTO VALVES AND CYLINDE
AND BLOW-BY THROUGH LOOSE GASKET
OUTSIDE HEAD GASKET LEAKAGE
HEAT CRACK AT VALVE S
CORE-HOLE PLUG LEAKA
AND CORROSION
DRAIN COCK LEAKAGE
HOT SPOT AT EXHAUST VALVE
RUST DEPOSIT IN WATER JACKET
RUST SLUDGE POCKETS AROUND VALVES
RUST CLOGGED WATER PASSAGES
CORE-HOLE PLUG CORROSION AND LEAKAGE
SIDE PLATE CORROSION AND GASKET LEAKAGE
WATER DISTRIBUTION TUBE CORRODED THROUGH, REDUCING VALVE COOLING

Figure 6-31.—Cooling system, showing likely trouble spots.

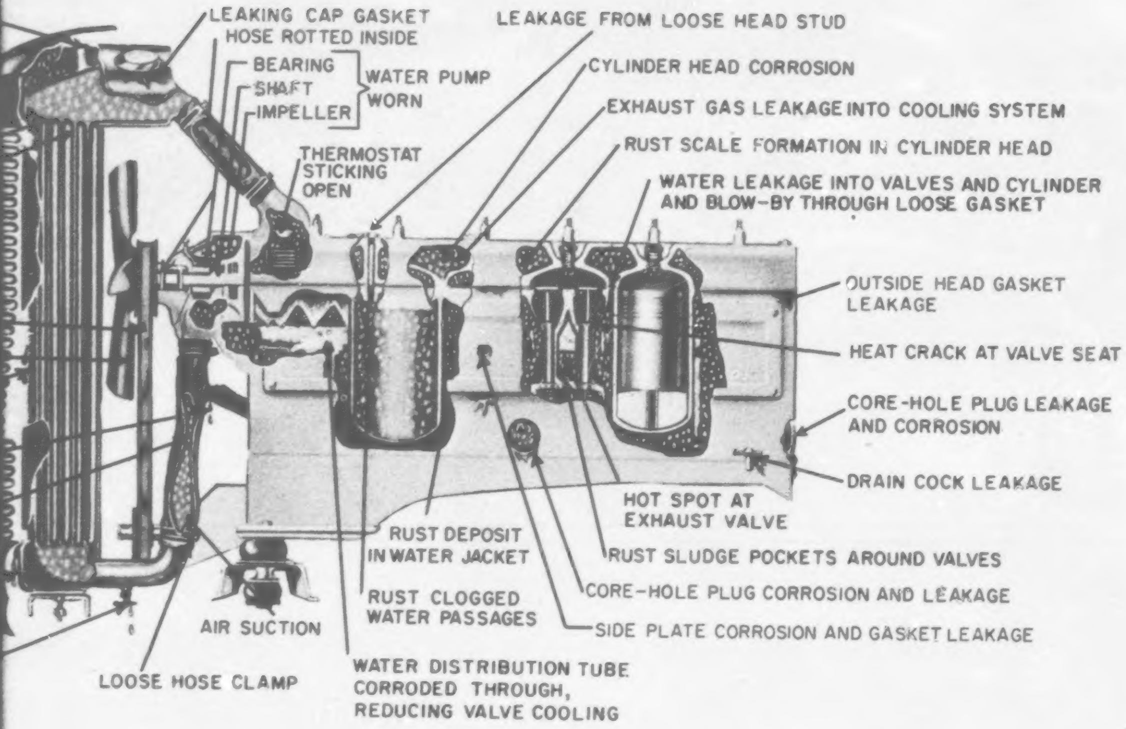
LEAKING CAP GASKET
HOSE ROTTED INSIDE
BEARING
SHAFT
IMPELLER
WATER PUMP WORN
THERMOSTAT STICKING OPEN
LEAKAGE FROM LOOSE HEAD STUD
CYLINDER HEAD CORROSION
EXHAUST GAS LEAKAGE INTO COOLING SYSTEM
RUST SCALE FORMATION IN CYLINDER HEAD
WATER LEAKAGE INTO VALVES AND CYLINDER AND BLOW-BY THROUGH LOOSE GASKET
OUTSIDE HEAD GASKET LEAKAGE
HEAT CRACK AT VALVE SEAT
CORE-HOLE PLUG LEAKAGE AND CORROSION
DRAIN COCK LEAKAGE
HOT SPOT AT EXHAUST VALVE
RUST DEPOSIT IN WATER JACKET
RUST SLUDGE POCKETS AROUND VALVES
CORE-HOLE PLUG CORROSION AND LEAKAGE
RUST CLOGGED WATER PASSAGES
SIDE PLATE CORROSION AND GASKET LEAKAGE
AIR SUCTION
LOOSE HOSE CLAMP
WATER DISTRIBUTION TUBE CORRODED THROUGH, REDUCING VALVE COOLING

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Figure 6-31.—Cooling system, showing likely trouble spots.

the manufacturer's instructions. Then run the engine for at least one-half hour after it reaches operating temperature. Drain the radiator again, refill once more with water, and run the engine 5 minutes more. After draining this water, refill the radiator, adding a rust preventive and, if the weather requires it, antifreeze solution. The addition of rust preventive is recommended especially when filling the cooling system of a new engine for the first time. If the radiator is not clean after flushing, remove it from the vehicle and take it to the shop for cleaning.

While cleaning and flushing the cooling system, also clean out the radiator air passages of insects, dirt, and other foreign matter by blowing them out with compressed air. Be careful in using the compressed air apparatus, because sudden bursts of air may damage the cooling system or other engine parts.

When servicing the cooling system check the condition of the hose and all hose connections. If there are bad leaks at connections, or if the hose collapses when grasped with the hand, it should be replaced.

A water hose can be removed by loosening the clamps, and with the fingers or water pump pliers rotate the hose to loosen it and make it easy to slip off. If the hose is frozen on, it will need to be cut off in order to remove it. Clean the surface where the hose fits before putting on the new hose. If the clamps are in good condition, they may be reused, otherwise replace them.

In replacing hoses, be sure that they are of the proper length and diameter. The diameter (inside dimension) is usually marked on the outside of the hose. Never use shellac to seal a leaking hose except in an emergency.

An overheated engine is easy to recognize by the temperature gage reading, radiator boiling or steaming, or by the knocking and laboring of the engine. The probable cause is insufficient water in the system, a defective thermostat, defective pressure cap, slipping fan belt, or a partially clogged radiator.

If the engine has a tendency to overheat or to run below the normal operating temperature, check the thermostat as a possible cause of trouble. Remove the thermostat and suspend it in a pan of water in which a thermometer also is suspended. Heat the water and observe whether the thermostat opens near the temperature at which it is designed to open. If it does not, the trouble has been located–the thermostat must be replaced.

An overheated engine may also be caused by trouble at various other points in the cooling system. Figure 6-31 shows where to look for trouble and indicates defects which may be found.

Before adding water to an overheated engine, let the engine cool sufficiently to prevent the possibility of cracking the cylinder block or head. Cracking is caused by the sudden contraction of the metal. In refilling the radiator, pour the water in slowly while the engine is running.

Water leaks can be detected by inspecting the radiator joints, hose connections, and other parts of the system where leaks can occur, and by observing the space under your parked equipment for wet spots. Small radiator leaks can be repaired by a special sealing compound which is added to the water in the radiator. If the radiator leaks badly, remove it from the vehicle and solder the leaking spots. Soldering instructions are given in Tools and Their Uses, NAVEDTRA 10085 (Series).

Water leaks may occur at any joint between the cylinder head and the engine block. These leaks can be serious. If not found promptly, water may find its way into the engine crankcase and form a sludge that will cause lubrication troubles. Tighten cylinder head bolts to stop these leaks. By using a torque wrench, proper and uniform pressure can be applied in tightening all bolts, and warping and distortion of the cylinder head can be prevented.

The fact that all connections in the cooling system look tight and secure does not necessarily mean that there are no leaks. It may be getting air from a very tiny leak which could speed up corrosion and rust. To check for air leaks, attach a hose to the overflow pipe and put the lower end of the hose into a container of water. If bubbles appear, they are a sign of air in the cooling system. These bubbles indicate leakage of water, including the antifreeze in it. Tightening or replacing hose clamps and connections is the usual remedy. Otherwise, the water pump should be suspected and checked.

There is no precise way to test the efficiency of the water pump. However, for some idea of how well the water pump operates, test it by squeezing the upper hose connection with your hand, with the engine warm and speeded up. If pressure is felt, the pump is operating normally. A defective water pump should be removed and either repaired or replaced, according to shop policy. If asked to repair a water pump, follow the manufacturer's directions for the pump of the particular vehicle with which you are working.

Exhaust gas, as well as air, can leak into the cooling system. Such a leak can result in great damage, because the gas tends to unite with the water to form corrosive acids. To test for exhaust gas leakage, disconnect the upper hose, remove the fan belt and the thermostat, and partially drain the cooling system. Start the engine and accelerate it quickly a few times. If the water level rises, or if bubbles appear in the water, exhaust gas is leaking into the cooling system. Installing a new cylinder head gasket and tightening the head bolts usually stop this trouble.

Worn, loose, or slipping fan belts are often the cause of overheating, especially when the engine is operating in low or second gear. Excess looseness or tightness can be determined by shoving in on the belt midway between the pulleys. The manufacturer's manuals specify the amount of slack that should exist.

If it is necessary to adjust the fan belt, first look at the type of device used to provide the fan belt takeup. Four methods of adjusting fan belts are illustrated in figure 6-32. To avoid unnecessary strain in the fan hub and driveshaft, never adjust the belt too tightly. The normal

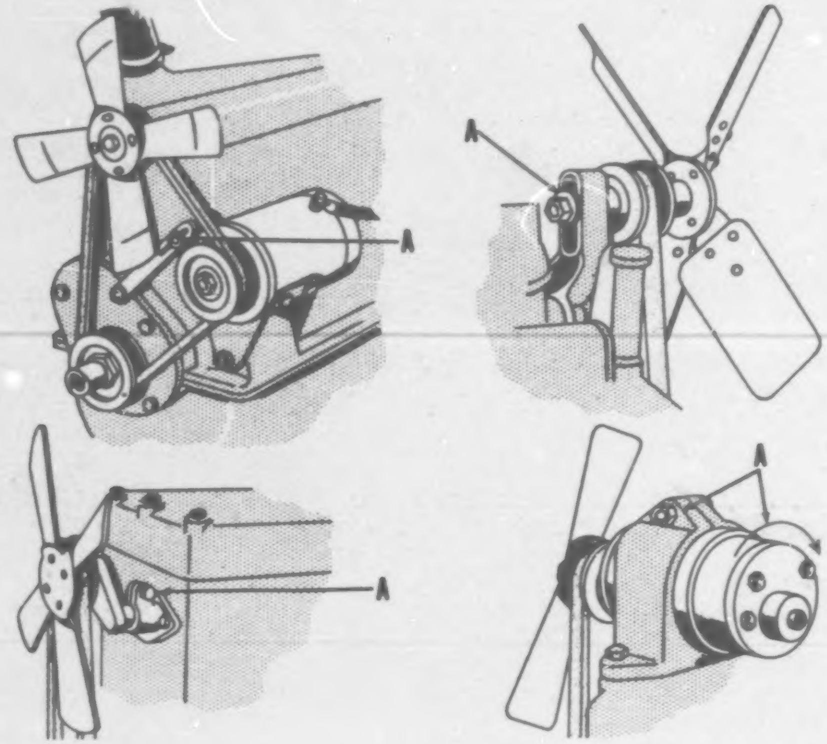

Figure 6-32.—Methods of adjusting fan belts as indicated by the letter A in each illustration.

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adjustment of the fan belt is 1/2 inch play at the longest span of the belt.

The fan blades should be checked for alignment. Proper alignment will permit the blades to turn without vibrating and will prevent them from cutting the hose connections or damaging the radiator core, which are close by. Each blade should turn in the same circle. This is checked by measuring the distance to the blade tips from a fixed point on the engine block. If necessary, bend the blades to obtain proper alignment.

LUBRICATING SYSTEM

This section explains the various types of engine lubricating systems and their components. The primary function of engine lubrication is to reduce friction between moving parts. Lubrication supplies a thin film of oil which prevents metal-to-metal contact, thus greatly reducing friction. The crankshaft, connecting rods, bearings, pistons, piston rings, valve stems, valve tappets, gears, drives, couplings, and bearings are the main parts which must be lubricated to guard against friction.

Helping to cool the engine is another function of the lubrication system. The oil goes through some very hot regions in the engine, and heat is absorbed by the oil, thus raising the oil temperature. The heat so absorbed is carried back to the oil pan, from which it is dissipated into the surrounding air.

Other purposes of lubricating oil are absorbing shocks between bearings and other engine parts, forming a seal between piston rings and cylinder wall, and helping to clean the engine parts.

As a shock absorbing agent, oil around the piston bearings and journals acts as a cushion against the jars they receive from the hammer-like blows of the thrusts of the piston. A load of as much as one and a quarter tons is suddenly thrown upon the top of the piston when combustion takes place. This sudden thrust on the piston is carried through the piston pin and connecting rod bearings. Oil helps quiet the piston movement and reduces the wear of its parts.

Piston rings must form a gastight seal with the cylinder walls. The lubricating oil delivered to the cylinder walls helps in this respect. The oil film also provides lubrication of the rings so that they can move easily in the piston ring grooves and on the cylinder walls.

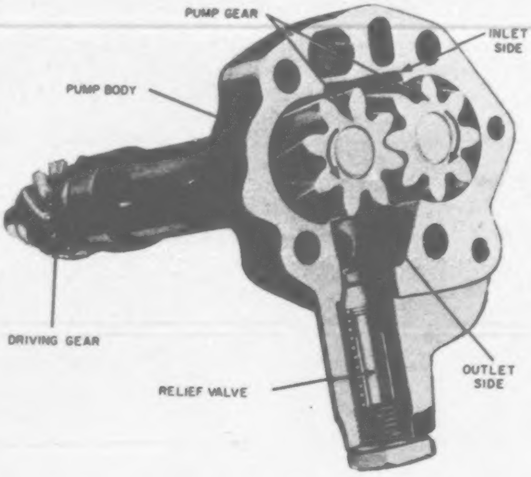
As oil circulates through the engine, it tends to wash off and carry dirt, particles of carbon, and other foreign matter into the crankcase, where the larger particles drop to the bottom of the pan. The oil filter removes many of the smaller particles.

All modern engines are lubricated under pressure. The oil supply is carried in the oil pan attached to the underside of the crankcase, from which it is drawn up and forced through a network of tubes, pipes, and drilled passages by the oil pump.

OIL PUMP

The oil pump is the most important part of the lubricating system. Depending on the design of the engine, the pump is mounted either inside or outside the crankcase. The two types of oil pumps generally used are the gear and the rotary.

In the gear type pump (fig. 6-33), a gear driven by the camshaft actuates a companion gear. Oil is forced into the pump cavity and around each gear. The action of the meshed gears creates a flow which forces the oil around



81.109

Figure 6-33.--Gear type oil pump.

the outside of each gear. To regulate this pressure the pump is provided with a pressure relief valve. This valve is a spring-loaded ball which rises when the pressure required to force oil to the engine parts is reached and allows any excessive oil to flow back into the oil pan through an opened port.

The rotary pump (fig. 6-34), uses a rotor or revolving device with lobes that match similarly shaped depressions in an outer rotor. When this pump operates, both rotors turn together; and the spaces between them fill with oil, which is then forced out from between the rotors through the various oil lines to the engine parts requiring lubrication. In the principle of its action, the rotor type is not unlike that of the gear type pump.

OIL GAGE

Figure 6-35 shows the circuit through which oil moves to reach every moving part of the engine. The normal oil pressure varies from 30 to 50 pounds per square inch (psi). To maintain the proper oil pressure, an oil pressure relief valve is put into the system and an oil pressure gage is provided on the instrument panel to register the operating pressure. The oil pressure gage is not the same as the oil level gage which indicates the oil level in the oil pan.

The pressure gage is mounted on the instrument panel of the vehicle. Marked off on a dial in psi, the gage indicates how regularly and evenly the oil is being delivered to all vital parts of the engine, and warns of any stoppages in this delivery. Pressure gages may be mechanical or electrical. In the mechanical type, the gage on the instrument panel is connected to an oil line tapped into the main oil supply passage leading from the pump. The pressure of the oil in the system acts on a diaphragm within the gage, causing a needle to register on a dial. In the electrical type, the oil pressure operates a device on the engine which signals electrically to a dash gage. The dash gage then indicates the oil pressure.

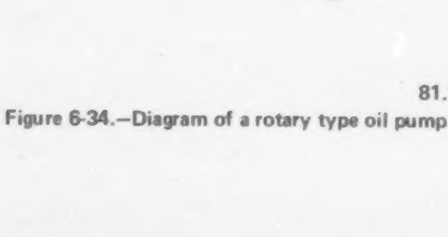


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Figure 6-34.—Diagram of a rotary type oil pump.

Some of the vehicles brought into the shop will not be equipped with an oil pressure gage, but will have electrically operated warning lights on the instrument panel, which flash on and remain lighted to indicate abnormal oil pressures.

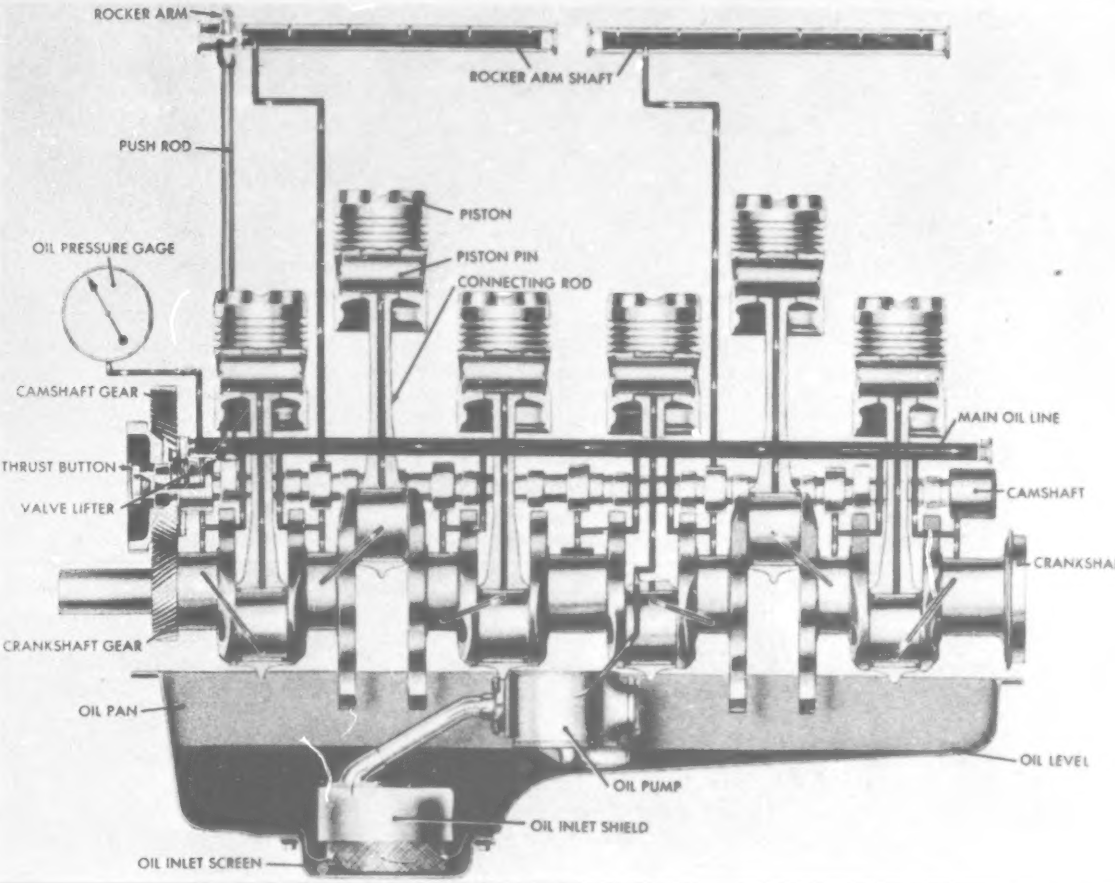
The oil level gage is a rod or dipstick inserted in the side of the engine so that it extends down into the oil in the oil pan. When it is withdrawn, the level of the oil in the pan is determined by observing the point the oil column has reached on the stick against the markings empty, low, and full. To assure an accurate reading, first wipe the stick clean; replace it in its socket; then remove it again to observe the oil column.

OIL FILTERS AND STRAINERS

Strainers and filters are placed in the lubrication system to provide constant cleaning of the oil as it circulates. Figure 6-36 shows a typical oil strainer, such as most vehicle manufacturers hinge to the inlet of the oil pump. It is a fine mesh bronze screen through which the oil must enter the pump from the oil pan. The strainer keeps large dirt and sludge particles from being drawn into the pump from the oil pan.

The oil filter (fig. 6-37) is located above the pump in the oil line. It removes most of the small impurities that have not been caught by the strainer. Thus the filter helps keep the oil clean and prevents entry into the engine of most of the very small foreign particles that could impair its efficiency.

Oil filters are of two types--the bypass filter, which filters only part of the oil coming from the oil pump; and the full flow filter, which


ROCKER ARM
ROCKER ARM SHAFT
PUSH ROD
PISTON
PISTON PIN
CONNECTING ROD
OIL PRESSURE GAGE
CAMSHAFT GEAR
MAIN OIL LINE
THRUST BUTTON
CAMSHAFT
VALVE LIFTER
CRANKSHAFT
CRANKSHAFT GEAR
OIL PAN
OIL LEVEL
OIL PUMP
OIL INLET SHIELD
OIL INLET SCREEN

29.96

Figure 6-35.—Basic units and oil passages of a pressure feed lubrication system.

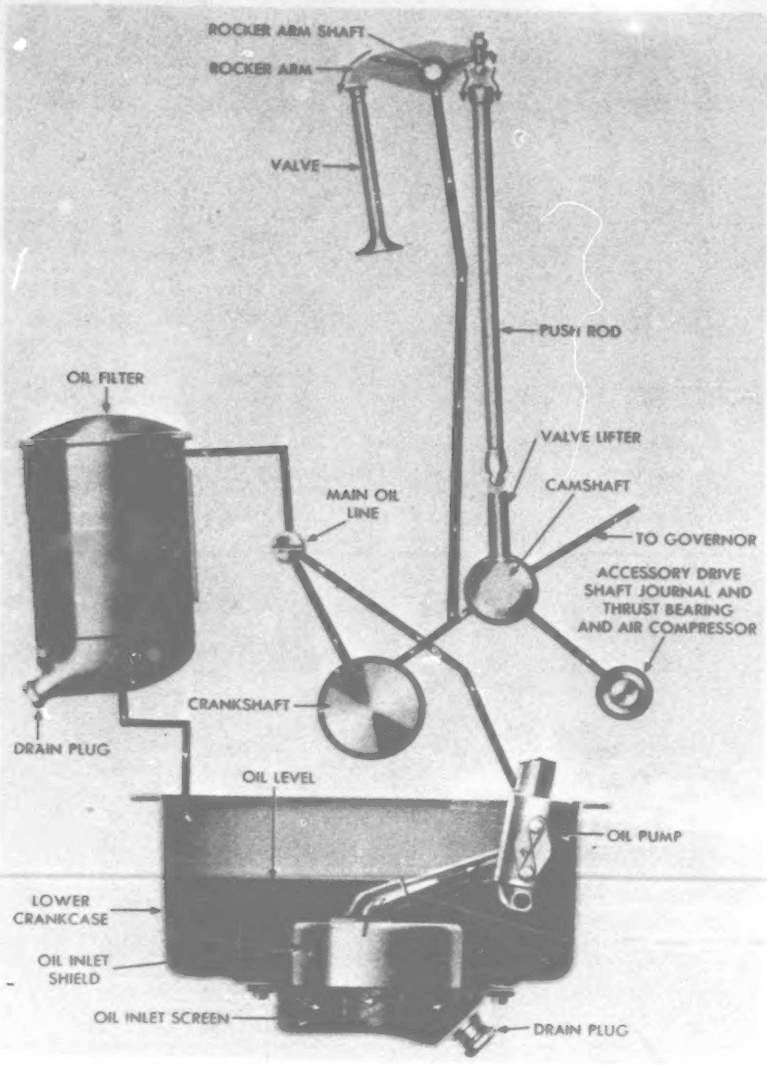
filters all the oil in circulation. The latter contains a spring-loaded valve, which opens to pass oil around the filter if it should become clogged with foreign matter.

Most engine filters are installed so that the oil can continue to circulate through the engine in case the filter becomes clogged.

CRANKCASE VENTILATION

There are two reasons for crankcase ventilation during normal operation. It removes gasoline and water that trickle into the crankcase during the normal process of combustion; such gas and water will mix with the oil and form a pasty sludge if allowed to remain in the crankcase. Ventilation also allows the crankcase to breathe in order to eliminate excessive pressure in the crankcase.

There are two methods of eliminating gasoline and water from the crankcase–the nonpositive method and the positive method. The nonpositive method depends on a breather tube. Air flows past the open end of the tube, evaporating the water and the gasoline and removing the vapors from the crankcase. One end of the breather tube opens into the crankcase above the oil level. The other end extends down under the vehicle, where there is

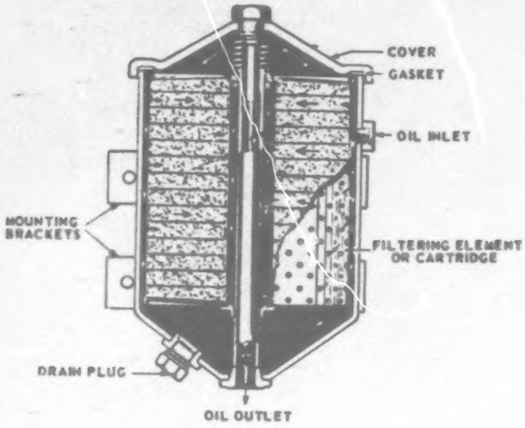

ROCKER ARM SHAFT
ROCKER ARM
VALVE
PUSH ROD
OIL FILTER
VALVE LIFTER
CAMSHAFT
MAIN OIL LINE
TO GOVERNOR
ACCESSORY DRIVE SHAFT JOURNAL AND THRUST BEARING AND AIR COMPRESSOR
CRANKSHAFT
DRAIN PLUG
OIL LEVEL
OIL PUMP
LOWER CRANKCASE
OIL INLET SHIELD
OIL INLET SCREEN
DRAIN PLUG

227.34

Figure 6-36.—Typical oil strainer.

sufficient airflow to create a low pressure at the open end of the tube (fig. 6-38). The pressure differential between the crankcase and the open end of the tube is sufficient to force any vapors out of the crankcase. Some breather tubes are placed so that the cooling fan will increase the flow of air passing over them, increasing their ventilating abilities.

In the positive method, air is drawn through the engine by an intake manifold vacuum; or, in other words, the intake manifold vacuum draws air through the crankcase to sweep vapors out of it (fig. 6-39). After picking up these vapors as it circulates through the crankcase, the air is forced upward and out of the engine through an opening in the valve cover and is then drawn



29.97

Figure 6-37.—Oil filter.

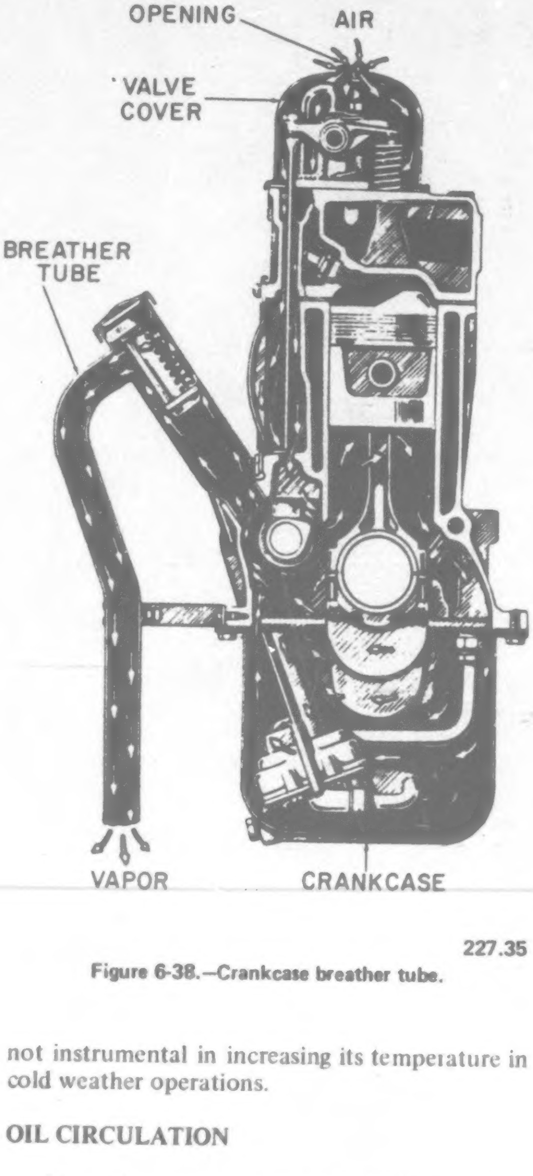
through a tube connected to the intake manifold.

To promote vaporization of volatile impurities and their removal from the crankcase, the operating temperature of the engine should be at least 140° F.

OIL TEMPERATURE REGULATOR

The oil temperature regulator (fig. 6-40) is used to prevent the temperature of the oil from rising too high in hot weather and to raise it in cold starts in winter. The regulator unit, which makes use of the water in the cooling system, is made up of a core and a housing. The core, through which the oil circulates, is exposed to the water which circulates through the housing. As the oil leaves the regulator, it is either cooled or heated, depending on the temperature of the water in the cooling system. From the regulator, the oil enters the oil passages that lead to the engine parts.

Some military vehicles use an oil cooler which consists of a radiator through which air is circulated by movement of the vehicle and the cooling fan. This radiator, through which oil passes to and from the oil pan through the engine passages, acts only to cool the oil and is not instrumental in increasing its temperature in cold weather operations.



227.35

Figure 6-38.—Crankcase breather tube.

OIL CIRCULATION

Now that parts of the lubrication system have been discussed, the different methods of circulating the oil through the various engine passages will be explained.

All modern engines are lubricated by a pressure system. The systems most generally employed are the splash, force-feed,

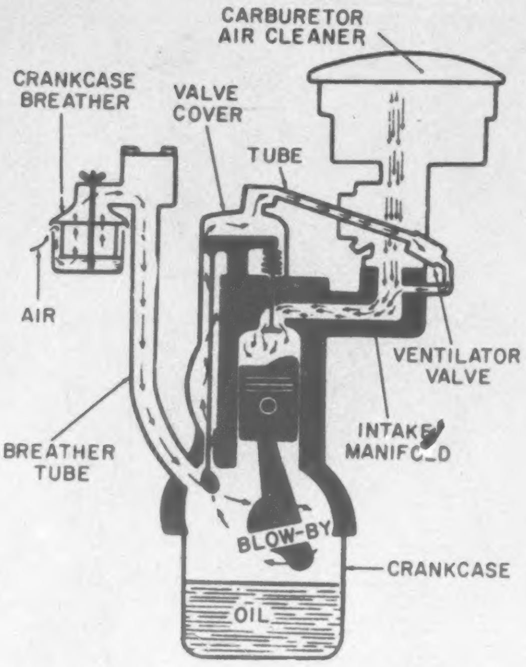


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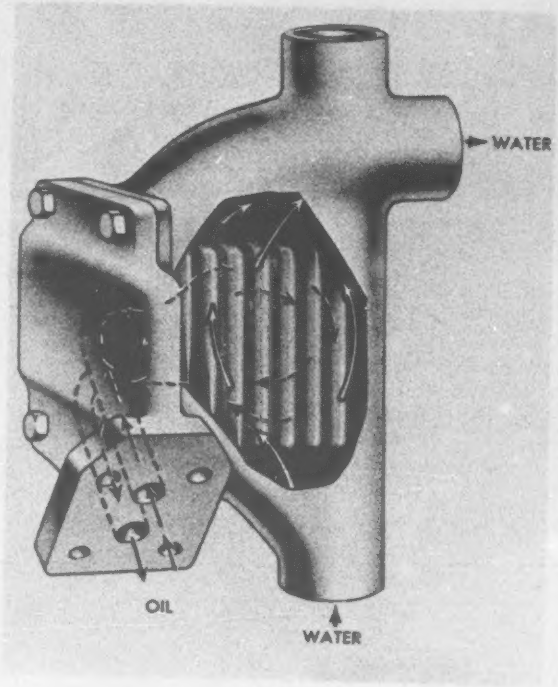
Figure 6-39.—Positive crankcase ventilation.



81.116

Figure 6-40.—Oil temperature regulator (cooler).

combination splash force-feed, and the full force-feed.

In the splash system, dippers on the connecting rods enter the oil in the crankcase with each revolution of the crankshaft and splash oil to the upper parts of the engine. The oil thus thrown upward in droplets and mist provides lubrication for the valve mechanism, piston pins, and other moving parts. The splash system is rarely found on modern engines, because its lubricating effect is too uncertain to meet today's heavy operating demands. On a full crankcase, it could mean overlubrication and a waste of oil; while on a partly filled crankcase, it could cause inadequate lubrication and failure of the engine.

The force-feed (or pressure feed) system (fig. 6-41) forces oil from the crankcase to the main bearings, camshaft bearings, and connecting rod bearings. The oil enters a line or a channel from the pump and then flows to the crankshaft bearings, which in turn feed the oil into drilled passages in the crankshaft. From these passages it flows through holes in the connecting rods into the piston pin bearings. The cylinder walls are lubricated by the oil thrown off from the connecting rods and piston pin bearings.

The combination splash force-feed system (fig.6-42) depends on oil splash and pressure to accomplish engine lubrication. The oil pump forces oil under pressure to the main and camshaft bearings and the valve mechanisms; but the connecting rods, the pistons, the piston pins, and the cylinder walls are lubricated by dippers splashing oil into the troughs underneath them. These troughs are kept filled by the oil pump, which delivers the oil through nozzles.

In the full force-feed system (fig. 6-43) all bearings, as well as the pistons and piston pins, are lubricated by oil under pressure from the pump. Oil enters the crankshaft oil passages, passes to the connecting rod bearings, enters

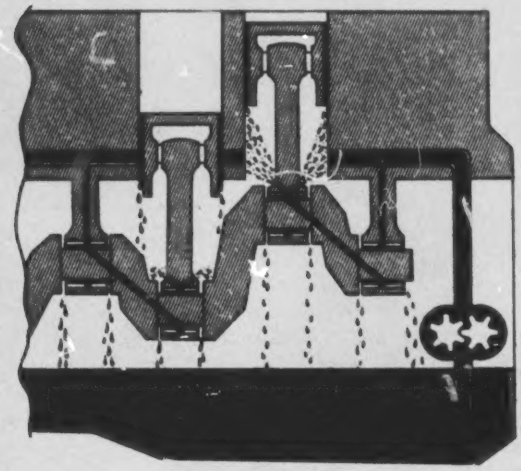


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Figure 6-41.–Force-feed lubrication system.

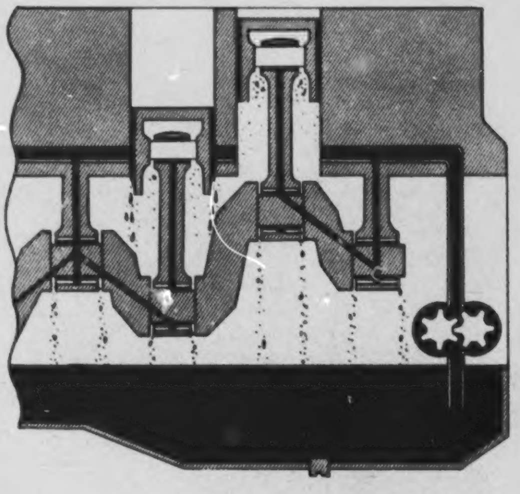

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Figure 6-43.–Full force-feed lubrication system.

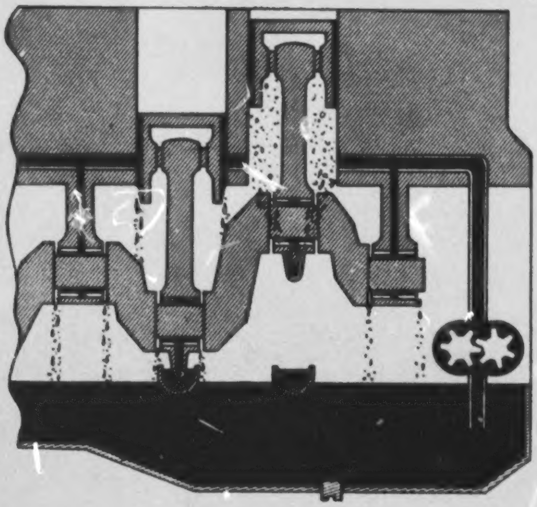

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Figure 6-42.–Combination splash force-feed lubrication system.

holes drilled in the connecting rods, goes up through the rod passages to the piston pin bearings, and helps lubricate both the pistons and the cylinder walls.

SERVICE AND MAINTENANCE OF LUBRICATION SYSTEMS

Check the oil level as previously directed and, if necessary, add additional oil for a full gage or dipstick reading. If the oil feels gritty to the fingers or has no body, it has lost its effective lubricating qualities. In any case, oil changes should be made in accordance with the Navy Preventive Maintenance Schedules. On most equipment the grade and quantity of the oil to be used will be found on a plate or chart in the cab. The oil should be changed more frequently in cold weather and in vehicles operated under dusty or other very unfavorable conditions. The supervisor will give specific directions about oil changes on such vehicles.

Drain the oil only after the engine has been run and is warmed up. This warmup period will thin the oil and stir up the sludge and foreign matter in the oil pan. Cold oil is thick and will not drain readily, and foreign matter will tend to stick to the sides of the oil pan when the engine is cold.

Upon the supervisor's instruction, remove the oil pan to clean out all sludgy and sedimentary matter when changing the oil. In doing so, steady the pan with your hand before undoing the last two nuts or bolts, so that it will not drop and be damaged. Before replacing the pan, install a new oil pan gasket and see that no leaks appear after the pan is in place and new oil has been added. Be sure also that the drain plug is tight, and that the filler cap, through which the crankcase is ventilated, is clean. Recheck the oil level to be certain that the oil column reaches the full marking on the dipstick.

Defective Oil Pressure Gage

Ordinarily, low oil pressure readings may be due to thin or diluted oil, excessive heating, an improper grade of oil, or a low oil level in the crankcase. If no pressure shows, or if the pressure is erratic even after replacing the old with new oil of the proper grade, a defective oil gage may be the cause. It is usually better to replace the entire gage unit than attempt repairs.

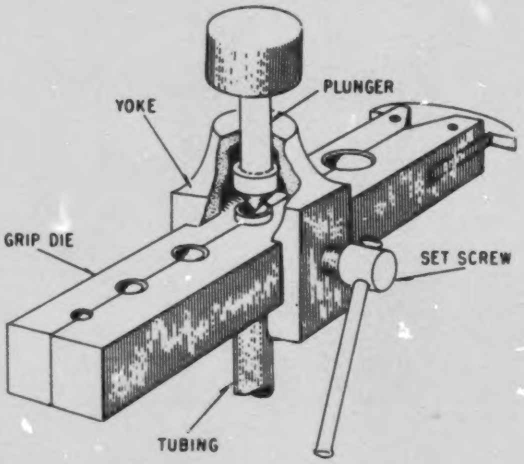
If the gage is not defective, check the entire outer surface for any oil leaks. Be sure that the fastening screws of the oil pan are tight. A leak in an external oil line usually can be repaired by tightening the fittings. Get into the habit of looking at the ground or pavement, over which a vehicle has been parked, for any oil spots that may indicate leakage.

Replacement of Oil Lines

It may be necessary for the ASM to make tubing where prefabricated replacement tubing is not available. Using the old tubing, measure the length, and allowing added length for inaccuracies in measuring, cut the tubing to desired length. Use a tube cutter or a fine toothed hacksaw. After the cut is completed, remove all burrs inside and outside, and clean the tube to make sure no cutting or foreign particles remain in the tube. Next, bend the tube to desired shape. The objective of tube bending is to obtain a smooth bend without flattening the tube. Aluminum or copper may be bent by hand if the bend can be distributed over a large enough length. If the bend must be short a tube bender must be used.

When the tube is cut to the correct length and bent to the desired shape, the ends are next flared if flared connections are to be used. A hand flaring tool (fig. 6-44) can be used for this purpose. This tool consists of a flaring block or grip die, a yoke, and a plunger or flaring pin. The grip die consists of two steel blocks hinged at one end and held in alignment by a pilot pin. A number of countersunk holes, varying in size to conform with tube diameters and countersinks matching standard flare angles and radii, are provided with half of the hole in each block. The yoke fits over the two halves of the grip die and has a setscrew used to lock the yoke in the desired position. The yoke also serves as a centering guide for the plunger. The plunger is tapered to the same angle as the countersunk holes in the grip die.

To flare the end of the tube, slip the fitting out and sleeve onto the tube and place the tube in the proper size hole in the grip die. The end of the tube should extend 1/64 inch above the surface of the grip die. Center the plunger over the end of the tube and tighten the yoke setscrew to secure the tubing in the grip and hold the yoke in place. The flare is made by



227.37

Figure 6-44.—Tube flaring tool.

striking the plunger several light blows with a hammer or mallet. Turn the plunger a half turn after each blow and make sure it seats properly before removing the tube from the grip die. After completing the flare, inspect to see that no cracks are evident. Be sure that you have put the connection on the tube before flaring or you will have to cut off the flaring, place the connection on the tube and make another flaring. (*Tools and Their Uses* NAVEDTRA 10085 (Series)) covers the basic concept of flaring.

Defective Oil Pump

Persistent low pressure readings or a zero reading could point to trouble in the oil pump. While a complete failure of the oil pump is rare, any wear of its moving parts is likely to impair its efficiency. If an attempt is to be made to repair the pump, follow the manufacturer's specifications and instructions. However, the policy of the shop may be to replace rather than repair a defective oil pump.

High pressure readings may be observed while the engine is warming up in cold weather, before the oil has reached operating temperature. After a brief warmup period, the gage indicator should return to normal. A persistent high pressure points to the possibility of a clogged oil line or a poorly operating pressure regulating valve. The latter trouble can usually be corrected by installing a spring with a different tension to operate the valve.

Changing Oil Filter Elements

Changing oil filter elements periodically will be a part of your job. Usually the filter elements are changed at the time the oil is changed in the crankcase. On new engines it may be changed (1) after the first 500 or 1,000 miles; (2) according to the manufacturer's instructions; or (3) according to shop policy. The filter element should be replaced by the type recommended by the manufacturer. Be sure that the new gasket under the cover is properly fitted, and that there are no oil leaks. Always check these points immediately after starting the engine.

In replacing the filter element, remove the drain plug from the bottom of the housing. Next, remove the cover by loosening the center bolt or clamp. Now lift out the old element, and wipe the inside of the housing with a clean cloth. Some filter housings do not have drain plugs. Therefore, first remove the cover; next remove the filter element and take out the dirty oil with a siphon gun; and then wipe the inside of the housing with a clean lintless cloth. Remove all traces of dirt or lint which remain inside. Install the new element. Finally, replace the drain plug and the cover, using a new gasket, or just the gasket and cover on filter housing without drain plugs.

On the type of filter that does not have a replaceable element, disconnect the oil lines to the old filter, dismount the filter, install the new one, and reconnect the oil lines.

GOVERNORS

The speed and the power output of an engine are determined by the combustion process in the cylinders. Since combustion depends upon air and fuel, the speed and output of an engine can be controlled by regulating the amounts of air and fuel supplied for the combustion process.

In diesel engines, a varying amount of fuel is mixed with a constant amount of compressed air inside the cylinder. A full charge of air enters the cylinder during each intake event. Since the quantity of air admitted is constant, combustion and, in turn, speed and power output are controlled by regulating the amount of fuel injected into the cylinders.

CONTROL OF ENGINE SPEED AND POWER

In a gasoline engine, speed and output are controlled by regulating the amount of air flowing into the cylinders of the engine. The carburetor is designed to measure the airflow. The amount of air and its velocity, in turn, control the quantity of fuel with which the air is mixed before the mixture enters the cylinders.

The quantity and velocity of air flowing into the cylinders is controlled by the throttle valve. By operating the valve, more or less air to the engine is admitted, and the carburetor automatically supplies the gasoline necessary to maintain the correct fuel-air ratio. Regulation of fuel or air supply by manual throttle control is adequate when engine speed and output requirements remain rather constant. However, the requirements of most engines used by the Navy vary because of fluctuating loads. The conditions under which towing equipment engines and engine of a generating unit operate are examples of fluctuating loads. In towing aircraft, tow tractors constantly tow heavy loads one way, but return with no load. In the case of a generating unit, the demands for electricity are variable. Manual throttle control is not adequate to hold engine speed reasonably constant during such fluctuations in load. For this reason, a speed control device, or governor is provided to prevent the engine from overspeeding and to allow the engine to meet changing load conditions.

The governor on electric generating units may be set for the generating unit to produce a desired voltage. If the load increases so that the generating unit is not supplying the desired voltage, the governor speeds up the engine until this voltage is produced and when the demand no longer exists, returns the engine to the low speed setting.

RELATION OF GOVERNOR TO FUEL SYSTEM

Even though it is not a part of the fuel system, a governor is directly related to this system since it functions to regulate speed by control of the fuel or the fuel-air mixture, depending upon the type of engine. In diesel engines, governors are connected in the linkage between the throttle and the fuel injectors. The governor acts, through the fuel injection equipment, to regulate the amount of fuel delivered to the cylinders. As a result, the governor holds engine speed reasonably constant during fluctuations in load. Since the speed and the output of a gasoline engine depend on the amount of fuel-air mixture available, governors, when used on these engines, are connected so that they control the amount of the mixture flowing from the carburetor to the intake manifold.

Governors have an adjustment for high speed, low speed, or both. To test the governor, use a tachometer to determine if the speed conforms with the manufacturer's specifications. To adjust or replace the governor requires that you consult and follow the information in the manufacturer's maintenance manual because the type of governor varies with the engine manufacturer.

Governors, like carburetors and fuel injection equipment, seem somewhat complicated unless one has a thorough understanding of the construction and operating principles of the equipment. As you progress through the ASM rating, you will acquire, through practical experience and study, the knowledge necessary to understand the factors which may seem complicated at the present. For the time being, it is enough to understand the relationship of speed-control devices to the fuel system of an engine. For this reason, the information on governors which is given in this manual is general in nature. Detailed information on governors can be found in the maintenance manual for the engine on which the governor operates.

SPEED-REGULATING GOVERNORS FOR DIESEL ENGINE

The type of load and the degree of control desired determine the kind of governor to be used on a diesel engine. Since all governors used on diesel engines control engine speed through the regulation of the quantity of fuel delivered to the cylinders, these governors may be classified under the general heading of speed-regulating governors. Governors used on diesel engines may also be classified in various other ways, such as according to the function or functions performed, the forces utilized in operation, and the means by which the governor operates the fuel-control mechanism.

Governors are designed to control engine speed under varying load conditions. Since the type of load and the degree of control desired vary from one type of installation to another, the primary function of a governor depends upon the requirements of a particular installation.

Some installations require that engine speed remain constant from a no-load to a full-load condition. Governors which function to maintain a constant speed, regardless of load, are called constant-speed governors. Governors which maintain any desired engine speed between idle and maximum speeds are classified as variable-speed governors. Speed-control devices which are designed to keep an engine from exceeding a specified maximum speed and from dropping below a specified minimum speed are classified as speed-limiting governors. (In some cases, speed-limiting governors function only to limit maximum speed.) Some engine installations require a control device that limits the load which the engine will handle at various speeds. Such devices are called load-limiting governors.

A governor may also be designed to perform two or more of the functions just listed. In this case, the operating mechanisms which perform the various functions are combined in a single unit.

SPRING-LOADED CENTRIFUGAL GOVERNORS

In most of the governors installed on diesel engines used by the Navy, the centrifugal force of rotating weights (flyballs) and the tension of a helical coil spring (or springs) are utilized in governor operation. On this basis, most of the governors used on diesel engines are generally called spring-loaded centrifugal governors.

In spring-loaded centrifugal governors, two forces oppose each other. One of these forces is the tension of a spring (or springs) which may be varied either by an adjusting device or by movement of the manual throttle. The other force is produced by the engine. Weights attached to the governor drive shaft are rotated, and a centrifugal force is created when the shaft is driven by the engine. The centrifugal force varies directly with the speed of the engine.

Transmitted to the fuel system through a connecting linkage, the tension of the spring (or springs) tends to increase the amount of fuel delivered to the cylinders. On the other hand, the centrifugal force of the rotating weights, through connecting linkage, tends to reduce the quantity of fuel injected. When the two opposing forces are equal, or balanced, the speed of the engine remains constant.

To illustrate how the centrifugal governor works, assume that an engine operates under load, and that the opposing forces in the governor are balanced, so that the engine speed is constant. If the load is increased, the engine speed decreases, resulting in a reduction in the centrifugal force of the flyballs. The spring tension then becomes the greater force, and it acts on the fuel-control mechanism to increase the quantity of fuel delivered to the engine. The increase in fuel results in an increase in engine speed until balance of the forces is again reached.

When the load on an engine is reduced or removed, the engine speed increases and the centrifugal force within the governor increases. The centrifugal force then becomes greater than the spring tension and acts on the fuel control linkage to reduce the amount of fuel delivered to the cylinders. This causes the engine speed to decrease until a balance between the opposing forces is again reached and engine speed becomes constant.

OTHER CLASSIFICATIONS OF GOVERNORS

Governors are also classified according to the method by which fuel-control mechanisms are regulated. In some cases, the centrifugal force of the rotating weights regulates the fuel supply directly, through a mechanical linkage which operates the fuel-control mechanism. Other governors are designed so that the centrifugal force of the rotating weights regulates the fuel supply indirectly, by moving a hydraulic pilot valve which controls oil pressure. Oil pressure is then exerted on either side of a power piston which operates the fuel-control mechanism.

Governors which regulate the fuel supply directly (through mechanical linkage) are called mechanical governors; and those which control the fuel supply indirectly (through oil pressure) are called hydraulic governors. Simple governors of the mechanical and hydraulic types are shown in figures 6-45 and 6-46 respectively.

Note that in the illustration of the mechanical governor the weights, or flyballs, are in an upright position. This indicates that the centrifugal force of the weights and the tension of the spring are balanced; in other words, the

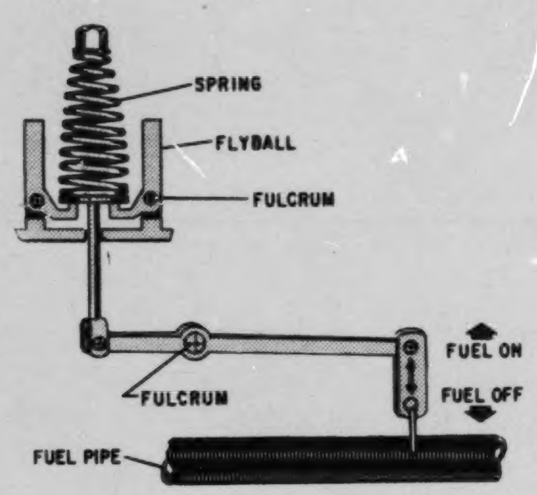


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Figure 6-45.—Simple mechanical governor.

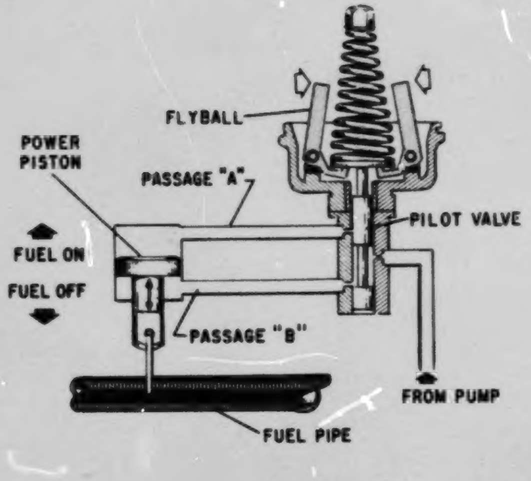

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Figure 6-46.—Simple hydraulic governor.

engine is operating at constant load and speed. In the case of the hydraulic governor, the positions of the parts indicate that the engine is responding to an increase in load with a resulting decrease in engine speed. Note that the weights tilt inward at the top. As engine speed decreases, the spring tension overcomes the contrifugal force of these rotating weights. When the spring tension is greater than the centrifugal force of the flyballs, the governor mechanism acts to permit oil under pressure to force the piston to increase the fuel valve opening. The increased fuel supply causes an increase in engine power output and speed. The governor regulates the fuel supply so that enough power is developed to handle the increase in load.

Hydraulic governors are more sensitive than those of the mechanical type. Also, the design of a hydraulic governor enables a comparatively small governing unit to control the fuel mechanism of a large engine. The mechanical governor is used more often on small engines, which do not require extremely close regulation of the fuel. Hydraulic governors are more suitable to large engines, in which more accurate regulation of fuel is necessary.

DANGER OF EXCESSIVE SPEED

Engines which are maintained in proper operating condition seldom reach speeds above those for which they are designed. However, there may be times when speeds become too high. The operation of an engine at excessive speeds is extremely dangerous because of the relatively heavy construction of the engine's rotating parts. If the engine speed is high enough, the high inertia and centrifugal force developed may cause parts to become seriously damaged or even to disintegrate. Therefore, it is essential that you know why an engine may reach a dangerously high speed, and how it may be brought under control when too much speed occurs.

CAUSES OF EXCESSIVE SPEED

In some two-stroke cycle engines, lubricating oil may leak into the cylinders as a result of leaky blower seals or broken piping. Even though the fuel is shut off, the engine may continue to operate, or even run away, as a result of the combustible material coming from the uncontrolled source. Engines in which lubricating oil may accumulate in the cylinders are generally equipped with an automatically operated mechanism which shuts off the intake air at the inlet passage to the blower. If no air shutoff mechanism is provided and shutting off the fuel will not stop an engine which is overspeeding, anything which can be placed over the engine's intake to stop airflow will stop the engine.

Excessive engine speeds more commonly result from an improperly functioning regulating governor than from lubricating oil accumulations in the cylinders. Stopping the flow of intake air is the method used to stop an engine which is overspeeding because of lubricating oil in the cylinders. The usual method of accomplishing an emergency shutdown or reduction of engine speed when the regulating governor fails to function properly is to shut off or decrease the fuel supply to the cylinders.

STOPPING FUEL SUPPLY

Shutting off the fuel supply to the cylinders of an engine may be done in various ways. The fuel-control mechanism may be forced to the no fuel position; the fuel line may be blocked by closing a valve; the pressure in the fuel injection line may be relieved by opening a valve; or the mechanical movement of the injection pump may be prevented These methods of shutting off the fuel supply may be done either manually or automatically.

OVERSPEED SAFETY DEVICES

Automatic operation of fuel and air control mechanisms is accomplished by overspeed safety devices. As emergency controls, these safety devices operate only in the event the regular speed governor fails to maintain engine speed within the maximum design limit. Devices which function to bring an overspeeding engine to a full stop by completely shutting off the fuel or air supply are generally called overspeed trips. Devices which function to reduce the excessive speed of an engine, but allow the engine to operate at safe speeds, are called overspeed governors.

All overspeed governors and trips depend upon a spring-loaded centrifugal governor element for their operation. In overspeed devices, the spring tension is great enough to overbalance the centrifugal force of the weights until the engine speed rises above the desired maximum. When an excessive speed is reached, the centrifugal force overcomes the spring tension and operates the mechanism which stops or limits the fuel or air supply.

GOVERNORS AS SAFETY DEVICES

When a governor serves as the safety device, the actual operation of the fuel or air control mechanism by centrifugal force may be brought about directly (as in a mechanical governor) or indirectly (as in a hydraulic governor). In the case of an overspeed trip, the shutoff control is operated by a power spring. The spring is placed under tension when the trip is manually set, and held in place by a latch. If the maximum speed limit is exceeded, a spring-loaded centrifugal weight moves out and trips the latch, allowing the power spring to operate the shutoff mechanism.

MALFUNCTIONS

At the beginning of this chapter, it was stated that air, fuel, and ignition was needed for an internal combustion engine to operate. When an engine turns over but fails to start or run, an investigation of the supply of these three necessities can often lead to the trouble. If all three are supplied to the engine properly, a more detailed analysis must be made to determine the cause. More about malfunctions of gasoline and diesel internal combustion engines appears in the next two chapters of this training manual.

INSPECTIONS

Inspections are conducted on aviation support equipment to insure that the equipment is operational, to determine what parts should be replaced in order to prevent equipment from becoming inoperative (preventive maintenance), and to determine the extent of repairs when equipment becomes inoperative. The preoperational or daily, periodic, and special inspections are given in Maintenance Requirement Cards (MRC). This information also appears in the Periodic Maintenance Requirements Manual for the equipment. Only the more complex aviation support equipment will have the manual and cards available.

The periodic MRCs for the mobile electric powerplant, NC-12A, gives changes in MRCs, purpose of inspections, definition of terms, work areas, reference publications, special tools and equipment needed, consumable material list, replacement parts list, and the periodic inspections to be conducted. The inspections are performed every 100 hours, 300 hours, 500 hours, and 1,000 hours of operation and every 13 and 26 weeks of the NC-12A being in use. Figure 6-47 gives an example of the maintenance requirement for the 100 hour and 1,000 hour inspections of the crankcase breather lines of the NC-12A.

The custodian of the equipment will perform the preoperational or daily inspections and the intermediate maintenance activity will perform the periodic inspections. Where MRCs are not available, consult the manufacturer's maintenance instructions for daily and periodic inspections.

Most inspections to determine the extent of repairs are covered where the equipment is covered in this manual.

INSPECTION OF METALS

It is very important that certain parts of support equipment be checked for cracks or other defects which might cause failure during operation. When a metallic part is suspected of having a tiny crack or other invisible defect, it is generally inspected by the penetrant method. The penetrant method is a nondestructive test, meaning it is performed on the part without damage to the part.

Penetrant Inspections

Penetrant inspection is a test for defects open to the surface in parts made of nonporous material. Penetrant inspection depends for its success upon the penetrating liquid entering the surface opening and remaining in that opening, making it clearly visible for the operator. It calls for visual examination of the part by the operator after it has been processed, with the visibility of the defect increased so that it can be detected. Visibility of the penetrating material is increased by the addition of a dye which may be either one of two types—visible or fluorescent.

The materials used in the visible dye penetrant inspection are available in aviation supply stock in the form of a complete inspection kit. Included in the kit are the following items: two spray cans of penetrant, dye remover–emulsifier, and developer. For replenishment purposes, these materials are also available as individual items. The chemicals are available in ordinary containers for use when dipping or brushing is desired.

The florescent inspection materials and equipment are also furnished in kit form. The complete equipment is contained in a metallic carrying case. Included are the following items: penetrant, penetrant cleaner, penetrant developer (both powder and suspension types), dauber for applying powder, and black light assembly complete with power transformer. The chemicals may be replenished individually from aviation supply stock.

The main disadvantage of penetrant inspection is that the defect must be open to the surface in order to let the penetrant into the defect. For this reason, if the part in question is made of material which is magnetic, the magnetic particle inspection is generally recommended. It is also essential that there be no contaminant within the defect which might either prevent the penetrant from entering or reduce its visibility.

First of all, the part to be inspected must be clean. This includes the removal of surface dirt, scale, paint, and oil, as well as removing any materials or compounds that might fill or cover the defects. If the part has been in contact with water, it may be possible to heat the part slightly to evaporate the water.

Penetrant is then applied to all surfaces. This may be done by dipping, pouring, brushing, or spraying. It is important that all suspect areas be wet with penetrant. The penetrant must be allowed to remain on the part for a period of

CARD 2	TIME 00:50	RTG ASM NO. 1	100 HOURS	POWER PLANT	ELEC PWR N/A HYD PWR N/A
TASK MIN.	WORK AREA	MOS.6371 NO. 1	PUBLICATION NUMBER NAVAIR 19-600-41-6-4	CARD SET DATE 1 July 1969	CHANGE NO.
30.0	2	1. Power plant: a. water pump and cross-over lines for evidence of leakage. b. generator and cooling fan belts for fraying, deterioration and proper tension (3/4" deflection midway between pulleys). c. generator for cleanliness and security. d. exhaust manifold for evidence of leakage around gaskets; asbestos covering for excessive oil saturation, deterioration and security. e. intake air assembly for security; blower for evidence of leakage around gaskets and bolts. f. rocker arm covers for evidence of leakage and security. g. crankcase breather line for evidence of chafing, deterioration and security. h. air box drains for obstructions and security; hand hold covers for evidence of leakage around gaskets. i. fuel pump for evidence of leakage and security. j. governor linkage for full, free travel and security. k. hydraulic governor for evidence of leakage and security.			
10.0	2,3	2. Radiators:			

CARD 6	TIME 01:05	RTG ASM NO. 1	1000 HOURS	POWER PLANT	ELEC PWR N/A HYD PWR N/A
TASK MIN.	WORK AREA	MOS.6371 NO. 1	PUBLICATION NUMBER NAVAIR 19-600-41-6-4	CARD SET DATE 1 July 1969	CHANGE NO.
		CONSUMABLES/REPLACEMENT PARTS Dry Cleaning Solvent — P-D-680 Antifreeze, Ethylene Glycol — 0-A-548			
45.0	2,3	1. Drain and flush radiators and engine block; replenish system with proper coolant; use ethylene glycol below 32° F sufficient for the degree of protection required.			
20.0	2	2. Remove crankcase breather lines; clean with solvent, air dry and reinstall.			

227.40

Figure 6-47.—MRCs for NC-12A.

time, called the penetration time. This allows the penetrant to seek and fill all surface openings. The length of the penetration time varies with the process and techniques used, the material of which the part is made, and the type of defects present. (See fig. 6-48).

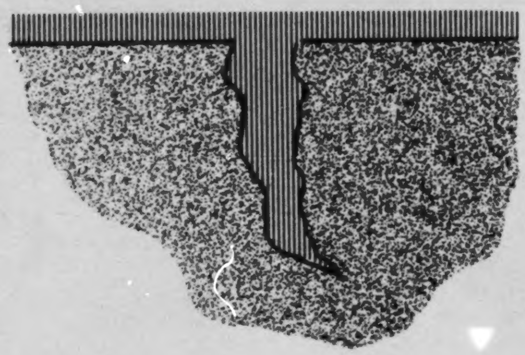

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Figure 6-48.—Penetrant on the surface seeps into the crack.

The excess surface penetrant is removed from the part by means of a forceful water spray. This operation does not remove the penetrant from deep defects, but does remove the penetrant on the surface. (See fig. 6-49).

A developer is then applied to the part before inspection. The function of the developer is to blot back to the surface the penetrant that is entrapped in fissures or defects in the part. The developer should be allowed to remain on the part for a time before inspection for defects. This elapsed time is to allow the developer to bring to the surface and magnify the traces of penetrant. Some types of defects in some parts may be detectable without the use of a developer, but for consistent and positive results, current instructions recommend that a developer always be used. A drying operation is necessary which increases the effectiveness of the method and, depending upon the type of developer used, either dries the wet developer or prepares the part for the application of the dry developer. (See fig. 6-50.)

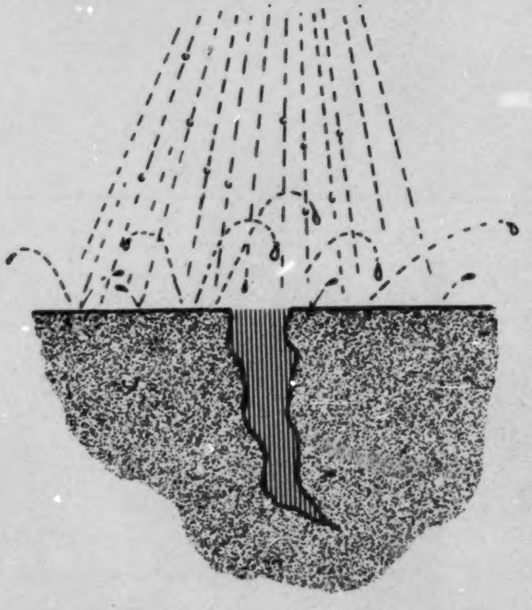

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Figure 6-49.—Removing penetrant from surface with water spray.

After the proper developing time has elapsed, the part is ready for inspection. If the penetrant used has a fluorescent dye in it, the inspection must be performed in a darkened area and under black light. If the penetrant used has a visible dye, then inspection can be performed under ordinary lighting conditions.

All traces of the developer should be removed from the part before it is returned to service.

Types of Processes

There are three acceptable processes of penetrant inspection. The selection of a suitable process depends upon the sensitivity required, the number of parts to be inspected, the surface condition of the part, the configuration of the part, and the availability of water, electricity, compressed air, and a suitable area for the inspection.

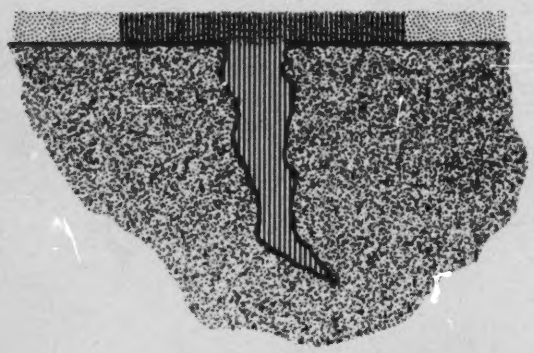

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Figure 6-50.–Developer drawing penetrant.

TYPE I–FLUORESCENT PENETRANT INSPECTION.–This process uses a complete, water-washable, fluorescent penetrant. This penetrant consists of an oil base which has extremely high penetrating qualities; to this base has been added an emulsifier and a highly fluorescent dye. The emulsifier makes the penetrant water-washable, and the dye causes the material to fluoresce a brilliant greenish yellow when viewed under black light. There are two developers available for use with the Type I process. For normal inspection purposes, these developers are equally sensitive and the selection of one or the other depends upon convenience of application. One developer is purchased and shipped in a dry powder form and is mixed with water to form a suspension which can be applied to the part by dipping, spraying, or applying with a brush. The other is a dry powder developer which can be applied to the part as received either by dusting or dipping.

TYPE II–POST EMULSIFICATION PENETRANT INSPECTION.–This process uses a penetrant which has an oil base to which has been added a dye which fluoresces brilliantly under black light. The penetrant used in the Type II process does not have an emulsifier in it. Washability must be imparted to this penetrant by the application of an emulsifying agent after the penetration step. This penetrant has extremely high penetration qualities and will enter the finest of defects. In order to make it possible to remove the surface excess of the Type II penetrant with a water wash, it is necessary to apply an emulsifying agent after the penetration time has elapsed. This emulsifier combines with the penetrant on the surface of the part as it unites with the penetrant makes it water-washable. The sensitivity of the Type II process is in part controlled by the length of time which elapses between application of the emulsifier and the removal of the combined emulsifier and penetrant. Variations in technique make it possible to detect not only the finest of deep cracks but also to show up shallow scratches and tool marks–shallow imperfections which are wider than they are deep. These shallow imperfections are difficult or impossible to detect with any other penetrant process.

One of the developers used with the Type II process is a dry powder. Since it is made up of particles with a rather large range in size, some of the smaller particles may float in the air unless care is taken in applying the powder to the processed part.

TYPE III–VISIBLE DYE PENETRANT INSPECTION.–This process uses a penetrant which consists of a solvent base to which has been added a visible dye. The dye penetrant is a brilliant red color under ordinary light. Inspection with this visible penetrant, after the necessary processing, is performed under ordinary lighting conditions.

Type III penetrant process is not suitable for use on extremely rough surfaces because of the difficulty in removing the penetrant from the surface.

Removal of the Type III penetrant from the surface is performed by wiping with paper towels or clean rags. On smooth surfaces the penetrant may be removed with rags only. However, it may be necessary to apply a dye cleaner to aid in removing the penetrant, and in this case it is not advisable to flush the surface with liquid cleaner; instead, a cloth should be dampened with the cleaner and the part wiped with the dampened cloth.

Dye cleaner is a solvent base solution which is used for cleaning parts prior to the application of the Type III penetrant and also for the purpose of assisting in removing the excess penetrant from the surface after the necessary penetrating time.

Dye Type III developer is a suspension having either a solvent or an alcohol base, which is applied to the part after it has been processed with the penetrant and after all excess surface penetrant has been removed.

While the Type III visible dye penetrant process has the advantage of being more portable than Types I and II and also requires less equipment, it is slower than the fluorescent process because on many parts it is harder to clean off the surface penetrant, and the cleaning is done on an area basis rather than by overall cleaning.

Interpreting Results

The success and the reliability of the penetration inspection depend upon the thoroughness with which the operator prepares the part, from the precleaning all the way through to the actual search for indications. It is not a method by which a part is thrown into a machine which separates the good parts from the bad. The operator must carefully process the part, search out indications, and then decide the seriousness of defects found in order to determine the disposition of parts with indications. Some of the indications of defects are shown in figure 6-51.

Penetrant inspections are important tools for finding defects before those defects grow into failures. As an operator, it is up to you, to get the most out of the method used.

Fluorescent indications, when viewed under black light, fluoresce brilliantly, and the extent of the indication marks the extent of the defect. Pores, shrinkage, lack of bond, and leaks will show as glowing spots; while cracks, laps, forging bursts, or cold shuts will show as fluorescent lines. Where a large defect has trapped a quantity of penetrant, the indications will spread on the surface. Experience in the use of the method allows interpretations to be drawn from the extent of the spread as to the relative size of the defects. Grinding into certain defects, or sectioning and viewing under black light will rapidly build up experience and knowledge of the character of defects lying below various types of indications. For best results, inspection should be done in a darkened area. The darker the area of inspection, the more brilliant the indications will show. This is extremely important when looking for very fine indications. The inspection table should be kept

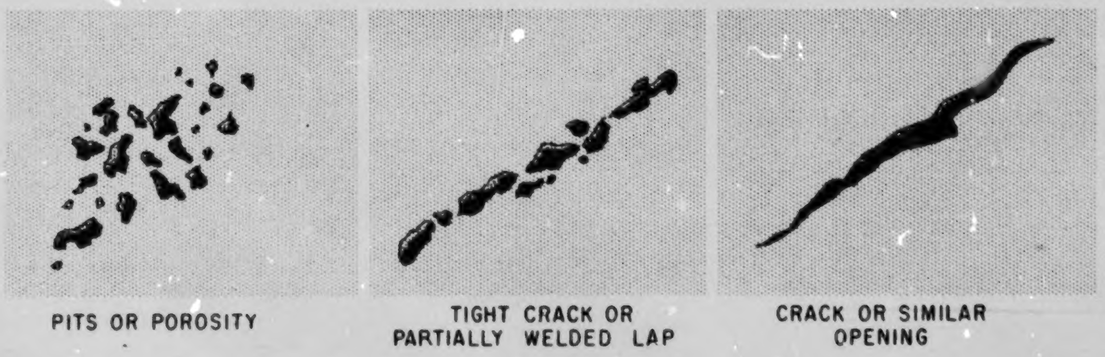

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Figure 6-51.—Types of defects.

free of random fluorescent materials. If penetrant has been spilled in the inspection area, on the table, or the operator's hands, it will fluoresce brilliantly and may confuse the operator.

Visible dye penetrant indications appear as red lines. As the developer dries to a smooth white coating, red indications will appear at the locations of defects. If no red indications appear, there are no surface flaws present. No special lighting is required for the visible dye penetrant inspection.

It is possible to examine an indication of a discontinuity and to determine its cause as well as its extent. Such an appraisal can be made if something is known about the manufacturing processes to which the part has been subjected. The extent of the indication, or accumulation of penetrant, will show the extent of the discontinuity, and the brilliance will be a measure of its depth. Deep cracks will hold more penetrant and therefore will be broader and more brilliant. Very fine openings can hold only small amounts of penetrant and therefore will appear as fine lines.

The most effective training tool for identifying and recognizing defects is a collection of parts with typical defects which can be referred to frequently. Parts that have been rejected because of defects should be clearly marked or partially damaged so that they will not be confused with acceptable parts. Unless the defects are extremely large, the indications will remain on the parts for several months or longer. If it becomes necessary to reprocess such parts, this can be done; but if process I is used, the sensitivity may be reduced somewhat by the contamination of the defect with old and possibly baked-in penetrant. Process II (with post-emulsification) does not have this disadvantage and parts can be rerun with no noticeable reduction in sensitivity. Visible penetrants tend to kill the fluorescent qualities in fluorescent penetrants used in processes I and II. After a part has been inspected using visible penetrant (process III), no attempt should be made to reprocess using fluorescent penetrant process I or II. The results will not be reliable. In all cases, clean thoroughly and degrease before reprocessing.

With penetrant inspections there are no false indications in the sense that such things occur in the magnetic particle inspection. However, there are two conditions which may create accumulation of penetrant that sometimes are confused with true surface cracks.

The first condition is a result of poor washing. If all the surface penetrant is not removed in the washing or rinse operation following the penetration time, the unremoved penetrant will be visible. This condition is usually easy to identify since the penetrant will be in broad areas rather than in the sharp patterns found with true indications. When accumulations of unwashed penetrant are found on a part, the part should be completely reprocessed. Degreasing is recommended for removal of all traces of the penetrant.

Another condition which may create false indications is where parts are press-fit together. For example, if a wheel is press–fit onto a shaft, the penetrant will show an indication at the fit line. This is perfectly normal since the two parts are not meant to be welded together. Indications of this type are easy to identify since they are so regular in form and shape.

TROUBLESHOOTING TECHNIQUES

Troubleshooting is defined as a systematic approach to isolating the cause of malfunctions of equipment, making use of sound reasoning plus the facts gained through the processes of deduction and elimination. In other words, troubleshooting is needed only after trouble starts. The processes of deduction and elimination may be based on a basic and simple visual inspection or on a series of tests or both. In their more advanced form the troubleshooting processes involve the use of complex test equipment such as the chassis dynamometer or the engine analyzer. Some of the troubleshooting testers have been covered in chpater 2 of this manual. Most of the troubleshooting techniques for aviation support equipment are covered in this manual in the chapters where the equipment is covered.

SAFETY

In the performance of his normal duties, the ASM is exposed to many potentially dangerous conditions and situations. No training manual, no set of rules or regulations, no listing of hazards can make working conditions completely safe. However, it is possible for the technician to complete a full naval career without serious accident or injury. Attainment of this goal requires that he be aware of the main sources of danger, and that he remain constantly alert to those dangers. He must take the proper precautions and practice the basic rules of safety. He must be safety conscious at all times, and this safety consciousness must become second nature to him.

Navy Safety Precautions For Forces Afloat, OPNAVINST 5100.19, and Safety Precautions For Shore Activities, NAVMAT P-5100, are the guide lines for the ASM to use in his duty of maintaining and operating ground support equipment. These are in addition to other directives concerning safety that are published by major commands on those specific hazards and procedures falling under the cognizance of those commands that will affect the ASM.

Equipment used by personnel working in confined spaces is a matter of considerable importance. Enough light should be provided so that the technician can see clearly what he is doing. The light provided should be insulated so that it does not present a shock hazard (confined spaces are usually quite warm, and a safety light produces additional heat, so perspiration may become a serious problem). When possible, explosion-proof equipment should be used in confined spaces, and protective clothing should be used if toxic fumes are known or suspected to exist within the space.

To prevent tragic and unnecessary damage to equipment, loss of human life, or personal injury, it is necessary to develop and to practice careful, safe, and clean work habits. All tools and equipment used should conform to Navy standards as to quality and type, and should be used only in the manner and for the purpose intended. All tools in active use should be maintained in good repair, and all damaged or nonworking tools should be replaced through supply channels. When a job is completed, or when work is interrupted, all tools should be counted and returned to the toolboxes or to the tool issue room. This should be done as carefully as a surgeon accounts for all his instruments following a major operation.

Practicing safety around machinery is always prudent. Smoking or open flames should not be present when fuel fumes or spilled fuel are present. Do not spill fuel on hot exhaust manifold or pipes as the heat may raise the fuel to its ignition temperature. It is good practice to use insulated tools and wear gloves when checking or working on ignition or starting systems. This helps prevent electrical shock should you or the tools you are using come in contact with a charged wire or terminal.

If the engine is hot when checking the level of coolant in the radiator, be sure to relieve the pressure in the system before removing the pressure radiator cap. If not relieved, this pressure could cause the hot coolant to spurt from the radiator when the cap is removed, causing serious burns. Also, burns are usually the result if you come in contact with the exhaust manifold or pipes when the engine has just been stopped. It takes several minutes for these parts to cool.

MODIFICATIONS AND CHANGES

Because equipment may have parts that are not as durable as expected or are unsafe because of defective material or arrangement, modifications and changes are ordered by the Naval Air Systems Command through changes. These modifications and changes will be incorporated by the intermediate maintenance level activity.

As an example of a change or modification, suppose that some using activities discovered that a metering jet of a certain carburetor was becoming deformed causing excessive gasoline consumption. A change would be issued requiring activities having this carburetor on equipment to substitute a replacement jet for the one that came with the carburetor.

In addition to the modifications and changes which become necessary because of faulty equipment, other changes are sometimes necessary because of faulty procedures. These changes are effected by the issuance of bulletins, which are issued to revise the operating procedures for aviation support equipment.

CHAPTER 7

RECIPROCATING GASOLINE ENGINES

Some reciprocating internal combustion gasoline engines use a fuel pump to feed the gasoline to the carburetor (some use gravity feed). The carburetor mixes air with the vaporized gasoline. The mixture next passes through the intake manifold and the intake valve to the cylinder, where the piston compresses the mixture. At this time the distributor directs an electric current to the spark plug. The spark plug fires the compressed mixture, and the resulting expansion forces the piston to turn the crankshaft.

This chapter explains the operations that are particular to the gasoline engine including the starting system, mixing the air and gasoline and delivery of the mixture to the cylinder, and igniting the mixture in the combustion chamber.

STORAGE BATTERY

The storage battery may be considered as the central unit of the gasoline engine starting, ignition, and generator or alternator systems. Thus, in tracing circuits or troubleshooting, the battery is the reference point from which other observations and tests are conducted.

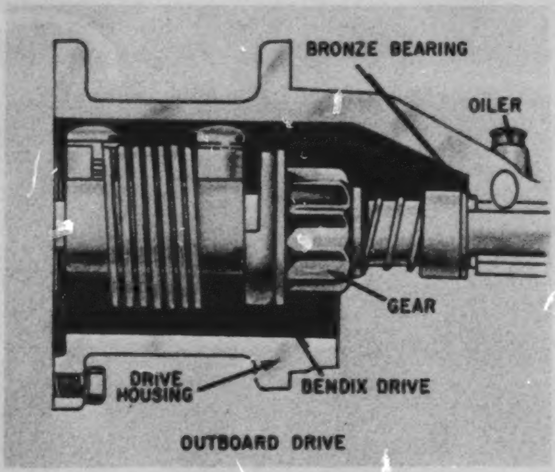
The battery supplies the electrical current for operating the starting motor and other units that are needed until the generator comes on the line. The battery also supplements the generator output when the generator is not producing sufficient current for all purposes. The manual NAVEDTRA 10314 (Series) can be referred to for a more thorough understanding of the storage battery.

STARTING SYSTEM

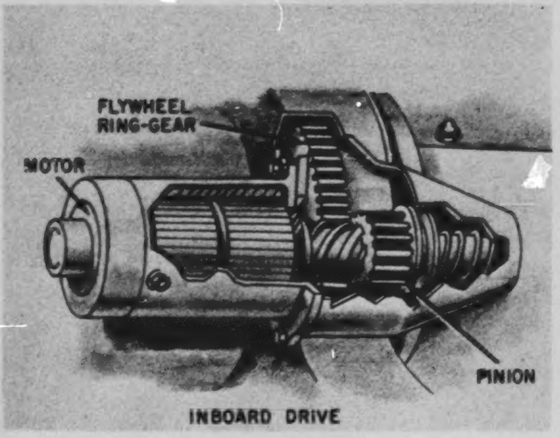
While gasoline engine starting and diesel engine starting are mechanically similar, some aids are used in diesel starting that are not needed in gasoline engine starting. The starting motor of most gasoline engines is an electrical motor that is energized by direct current from the battery. This starting motor changes electrical energy to mechanical energy. It does this by a gear reduction system that transmits the cranking power to the engine. The method most used for gear reduction makes use of a pinion gear on the cranking motor armature shaft, which, in operation, meshes with teeth on the engine flywheel. There are from 10 to 16 teeth on the flywheel for every tooth on the cranking motor pinion. Therefore, the cranking motor armature revolves 10 to 16 times for every revolution of the engine flywheel. In operation, the starter armature revolves at a rate of 2,000 to 3,000 rpm, thus turning the engine crankshaft at speeds up to 200 rpm.

When the engine begins to operate, it may be speeded up to 3,000 to 4,000 rpm. If the cranking motor did not demesh from the flywheel teeth, the cranking motor armature would be spun at speeds up to 60,000 rpm. These high speeds would throw the windings from the slots in the armature and the segments from the commutator. To prevent this, various methods of meshing and demeshing the cranking motor pinion with the flywheel have been devised.

The BENDIX DRIVE (fig. 7-1) is one device that accomplishes meshing and demeshing of the drive pinion with the flywheel. It relies upon the principle of inertia to cause its pinion to mesh.



OUTBOARD DRIVE



INBOARD DRIVE

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Figure 7-1.—Starting motor with Bendix drive.

When the starter is not operating, the pinion is out of mesh and entirely away from the flywheel gear. When the starter switch is engaged and the total battery voltage is impressed on the starter, the armature immediately starts to rotate at high speed. The pinion, being weighted on one side and having internal screw threads, does not rotate immediately with the shaft but, because of inertia, runs forward (outboard drive) or back (inboard drive) on the revolving threaded sleeve until it meets or engages with the flywheel gear. If the teeth of the pinion and the flywheel meet instead of engaging, the drive spring allows the pinion to revolve and forces it into mesh with the flywheel. When the pinion gear is fully engaged with the flywheel gear, the pinion is then driven by the starter through the compressed drive spring and cranks the engine. The drive spring acts as a cushion while the engine is being cranked against compression. When the engine fires and runs on its own power, the flywheel drives the pinion at a higher speed than does the starter, causing the pinion to turn in the opposite direction on the threaded sleeve and automatically disengage from the flywheel. This prevents the engine from driving the starter. Several other types of inertia or Bendix-type drives are also in use. Although they may differ considerably in looks and construction, their method of operation is similar in many respects to the Bendix drive just discussed.

The overrunning clutch provides positive meshing and demeshing of the starter pinion gear and engine flywheel gear. The shell and sleeve assembly of the clutch (fig. 7-2) is driven by the starter armature shaft. The rotor assembly is connected to the pinion gear which meshes with the engine flywheel gear. Spring-loaded steel rollers are located in tapered notches between the shell and the rotor. The springs and plungers hold the rollers in position in the tapered notches. When the armature shaft turns, the rollers are jammed between the notched surfaces, forcing the inner and outer members of the assembly to rotate as a unit and crank the engine. After the engine is started, the flywheel rotates faster than the pinion gear, thus tending to work the rollers back against the plungers (fig. 7-2), and thereby causing an overrunning action. This action prevents excessive speed of the starter. When the starter is released, the collar and spring assembly pulls the pinion out of mesh with the flywheel gear.

The DYER DRIVE (fig. 7-3) is another type of starting motor drive which combines some of the principles of both the Bendix and the overrunning clutch drives. The Dyer drive is used primarily on heavy duty gasoline and diesel engines. It provides complete and positive meshing of the drive pinion and the flywheel teeth before the starter motor is energized.

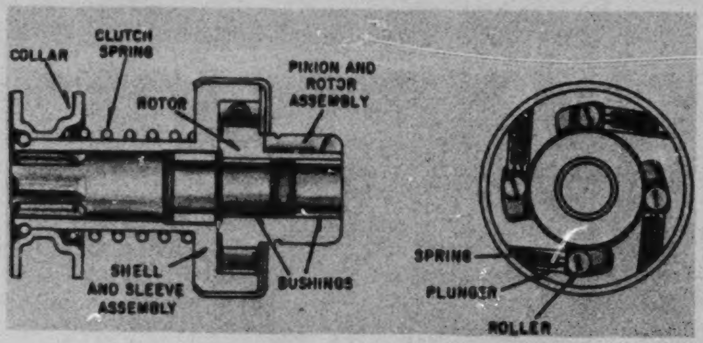
COLLAR
CLUTCH SPRING
ROTOR
PINION AND ROTOR ASSEMBLY
SHELL AND SLEEVE ASSEMBLY
BUSHINGS
SPRING
PLUNGER
ROLLER

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Figure 7-2.—Typical overrunning clutch construction.

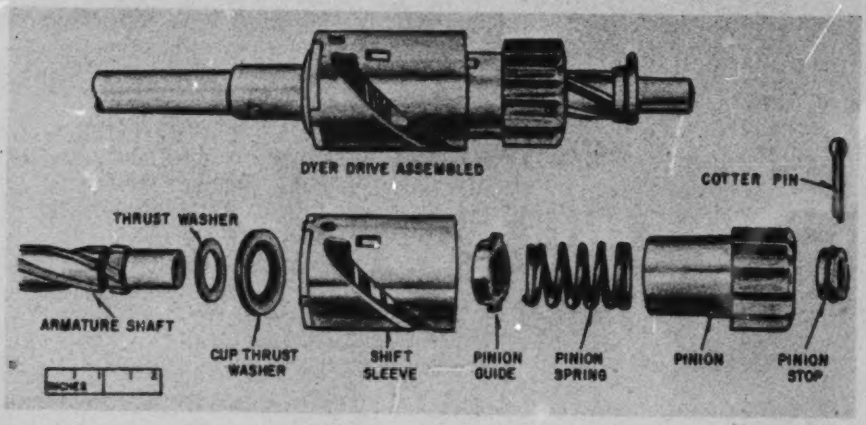
DYER DRIVE ASSEMBLED
COTTER PIN
THRUST WASHER
ARMATURE SHAFT
CUP THRUST WASHER
SHIFT SLEEVE
PINION GUIDE
PINION SPRING
PINION
PINION STOP
INCHES
1
2

Figure 7-3.—Dyer drive.

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As shown in figure 7-1, the entire starting motor can be removed as a unit. Thus, when the starting system malfunctions and the trouble has been determined to be in the starting motor, it is removed for inspection and repair. After the starting motor has been removed, the mechanical components can be removed from the end of the shaft that protrudes into the flywheel housing. The pinion and the spring are the parts that usually wear or break and need replacing.

NOTE: The cranking motor runs only for a few seconds each time it is used and carries a great overload when it is running. To carry such a heavy load, it draws a high current. This current—100 to 550 amperes, depending on the type of engine it cranks—causes the cranking motor to heat up quickly. To keep the cranking motor from overheating, NEVER run it longer than 30 seconds at a time. If the engine does not start within that time, let the cranking motor cool off for several minutes before cranking it again.

IGNITION SYSTEMS

Ignition of the fuel-air mixture in an engine cylinder may be accomplished by either of two methods–by heat of compression as in diesel engines, or by electric spark as in gasoline engines. This section pertains to ignition by electric spark only.

Spark ignition may be subdivided into two classes–battery and magneto. With either, the fundamental job is to step up low voltage to a much higher value (15,000 to 20,000 volts) and to deliver the high voltage to the spark plugs at the proper time. The high voltage is capable of pushing current from one spark plug electrode to the other through the high resistance set up by the gas pressure in the combustion chamber.

BATTERY IGNITION SYSTEM

The voltage of the vehicle battery is not high enough to force a current across the spark plug electrodes. To obtain the high voltage necessary (approximately 20,000 volts), a step-up pulse transformer (ignition coil) is used. The high voltage created is then delivered by the distributor, at the right time, to the spark plug of the correct cylinder. The high voltage forces a current across the spark plug electrodes, creating a spark, which ignites the air-fuel mixture in the cylinder.

The battery ignition system consists of two circuits, the primary and the secondary. Figure 7-4 illustrates the two circuits and their components for a conventional system using a 12-volt or a 24-volt battery.

IGNITION RESISTOR.–An ignition resistor, sometimes called a ballast resistor, is used in all conventional ignition systems that operate on 12 or 24 volts. The resistor reduces the voltage and current flow across the breaker points. During low-speed operation, primary circuit current flow is high and the temperature of the resistor increases, its resistance increases, and current flow decreases, thus prolonging breaker point life. During high-speed operation, primary circuit current flow is low and the temperature of the resistor decreases, its resistance decreases, and current flow increases, thus meeting high-speed requirements. During starting, when starter current draw might decrease the voltage available to the coil to a point where starting would be difficult, the resistor is bypassed. This allows full battery voltage to flow to the coil to ensure that a strong spark is created at the spark plugs even under adverse conditions.

IGNITION COIL.–The primary winding of the ignition coil consists of a few hundred turns of heavy wire wrapped around a laminated soft-iron core (fig. 7-5). When current is flowing in the primary circuit, a magnetic field is set up about this coil. The secondary winding consists of many thousand turns of very fine wire around the primary coil. The magnetic field from the primary coil surrounds or "links" the turns of wire on the secondary winding (fig. 7-5).

If the flux linking a coil is varied or changed in any way, an electromotive force is induced in the turns of the coil. This is a manifestation of the basic principle upon which both the electric generator and the induction coil work. In an induction coil, such as an ignition coil, a magnetic field is set up by current from the battery flowing through the primary circuit. Unless this current flow is changing to vary the strength of the magnetic field, no voltage is induced in the secondary winding.

Since both the primary and secondary windings of an induction coil are stationary windings, some means other than movement of the windings is used to change the magnetic flux linking the coils. This effect is created by a make-and-break device (breaker points) in the primary circuit. When the breaker points are closed, current flows through the primary coil, and the magnetic field builds up around it. The magnetic lines of force link the primary and secondary windings and induce voltage in each winding. In the primary winding, the induced voltage opposes the battery voltage. For this reason, the magnetic field is not built up instantly, but requires a fraction of a second to reach full strength. This is called the saturation time.

BREAKER POINTS.–The make-and-break device, which consists of a set of contact points and a spring, is located in the distributor. The purpose of this device is to open the primary circuit, causing the magnetic field to collapse. This collapse induces a high voltage in the secondary winding, and causes a brief but strong flow of current in the secondary circuit. The

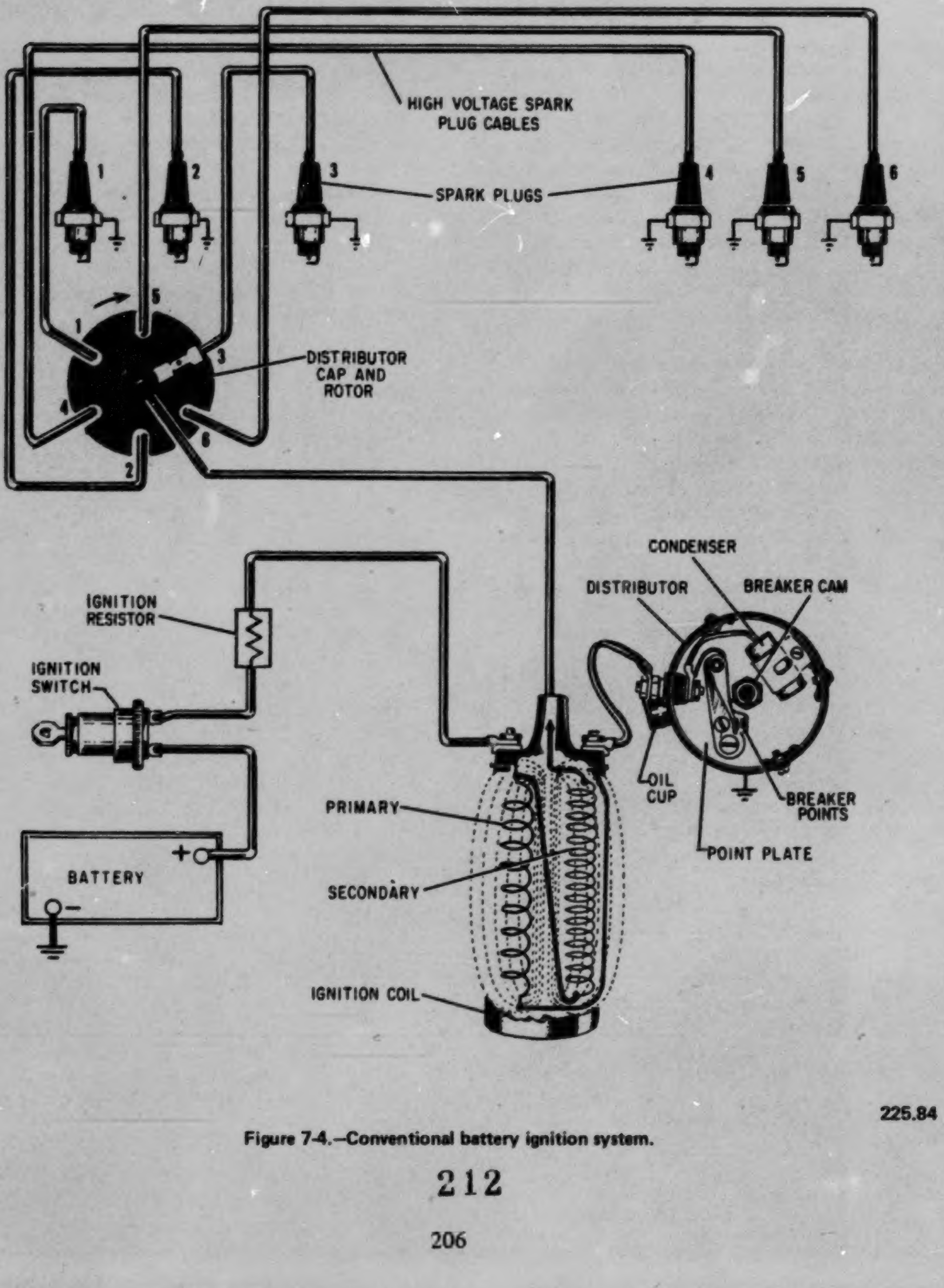
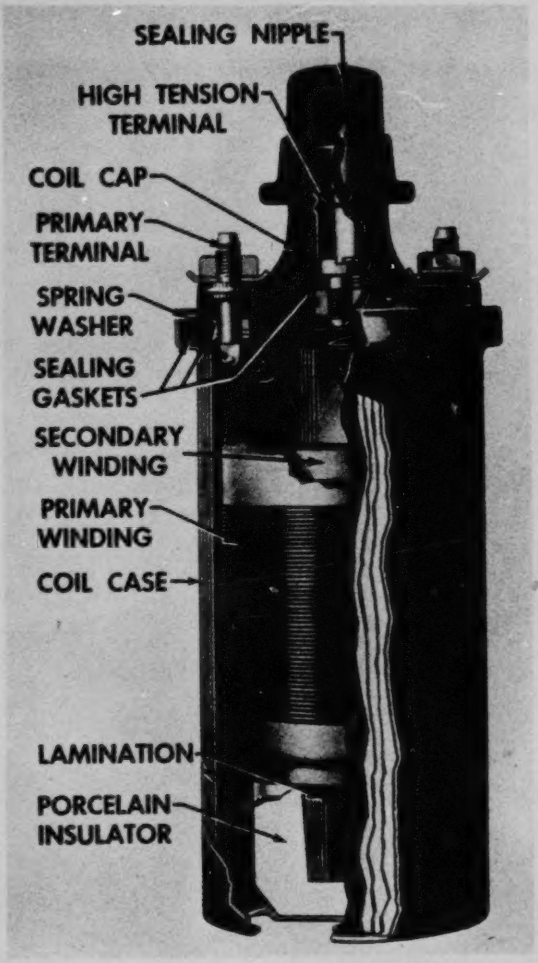

HIGH VOLTAGE SPARK PLUG CABLES
1
2
3
SPARK PLUGS
4
5
6
1
5
3
4
2
6
DISTRIBUTOR CAP AND ROTOR
CONDENSER
DISTRIBUTOR
BREAKER CAM
IGNITION RESISTOR
IGNITION SWITCH
OIL CUP
BREAKER POINTS
POINT PLATE
PRIMARY
+
BATTERY
−
SECONDARY
IGNITION COIL
225.84

Figure 7-4.—Conventional battery ignition system.



77.156
Figure 7-5.—Sectional view of an ignition coil.

flow of current in the secondary circuit causes a spark as it flows across the gap of the particular spark plug which is connected into the secondary circuit by means of the distributor.

The collapse of the magnetic field also induces a high voltage in the primary coil.

CAPACITOR.–If the flow of current through the primary circuit due to the collapsing field were allowed to continue, it would cause arcing across the breaker points. To reduce this arcing, a capacitor (condenser) is wired in parallel with the breaker points and grounded through the distributor housing. The capacitor takes up the current from the induced primary voltage, allowing the magnetic field to collapse very quickly and induce a high secondary voltage. The result is a good hot spark, which is required to ignite the fuel-air charge.

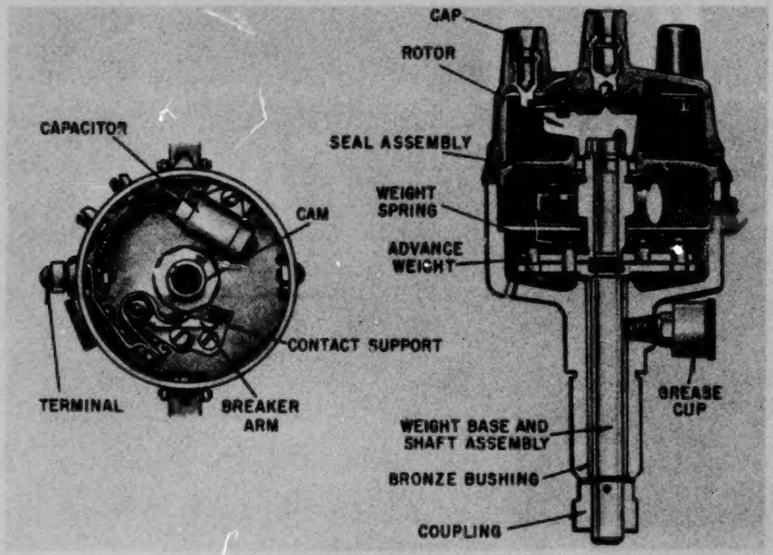
Induced voltages in the primary and secondary windings depend on the number of turns of wire in the two windings. The voltage induced in the secondary winding when the field collapses may be as high as 25,000 volts. The spark is usually created across the plug gap at a lower voltage–approximately 10,000 volts.

DISTRIBUTOR.–Figure 7-6 is a side and top view of a distributor unit.

The distributor cap has a center terminal for the high-tension lead from the secondary coil, and separate terminals for leads to the spark plugs. The cap fits over the bowl of the distributor housing that contains the capacitor, rotor, breaker points, and the breaker cam. The breaker cam and the rotor rotate at one-half engine speed on a shaft which is driven from the camshaft. The rotor conducts the high voltage from the secondary to the separate spark plug leads.

The mechanism is timed so that the rotor is adjacent to one of the spark plug leads each time the primary circuit is broken. In figure 7-6 the spark plugs and cylinders are numbered in a standard manner, beginning with number 1 at the front of the engine, back to number 6 (6-cylinder engine) at the rear of the engine. The leads from the distributor cap are arranged so the rotor will make contact and send high voltage to the spark plugs in the following firing order–1-5-3-6-2-4.

BREAKER CAM.–The breaker cam is six-lobed for a 6-cylinder 4-stroke cycle engine. Therefore, the breaker points will open and close six times with each revolution of the distributor shaft. These contact points close and open the primary circuit, so that six times in each two revolutions of the engine, the magnetic field in the coil will be built up and allowed to



227.43

Figure 7-6.—Distributor.

collapse. The breaker cam and rotor rotate together, and the rotor is aligned with the proper spark plug contact each time a cam lobe opens the primary circuit, collapsing the magnetic field and producing a high voltage in the secondary circuit.

TIMING ADVANCE UNIT.—Timing advance is accomplished in the distributor. A short time is required to ignite and burn the air-fuel mixture and develop power, and this time is practically the same at all engine speeds. At high speeds, the timing must be advanced so the sparks will occur earlier than at low engine speeds if combustion is to be completed at the most effective time in the operating cycle.

There are two types of automatic-timing advance mechanisms, and they may be used separately or together. The centrifugal-advance mechanism (fig. 7-5) is operated by a pair of weights that are thrown out against spring tension as the engine speed increases. Movement of the weights advances through a linkage to the breaker cam. This mechanism, usually found in the lower part of the distributor housing, provides a smooth advance and retard of the timing with changes in engine speed.

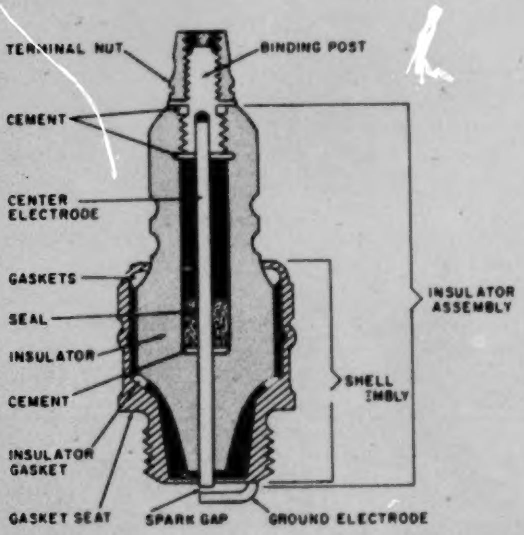
The vacuum-advance mechanism advances and retards the timing according to engine load, and uses a spring-loaded diaphragm connected by a linkage to the distributor and by a vacuum passage to the carburetor. The opening to the carburetor is on the atmospheric side of the throttle when the throttle is in idling position. There is no advance in this position since the opening is under atmospheric pressure. As the throttle is opened, it swings past the opening of the vacuum passage, exposing the advance-mechanism diaphragm to intake manifold vacuum. The diaphragm operates the advance-mechanism linkage and rotates the breaker plate and breaker points in the direction of distributor rotation, causing the breaker points to be opened earlier, advancing the time that the spark occurs in the cylinder.

SPARK PLUGS.—Spark plugs are installed in each cylinder of an engine. The plugs provide the fixed air gap across which the high voltage from the coil jumps to create the spark that ignites the air-fuel mixture in the cylinder. A cutaway view of a spark plug is shown in figure 7-7.

Plugs come in different thread sizes; such as 10mm, 14mm, 18mm, and 7/8 inch. The ten-millimeter plug will carry numbers beginning with "10"–such as 104, 106, etc. The fourteen-millimeter plug will carry the numbers beginning with "4"–such as 44, 46, 47, etc. Eighteen-millimeter plugs carry numbers beginning with "8" like 82, 83, 85, etc. And seven-eights-inch plugs carry numbers beginning with "7"–such as 73, 74, 75, etc.

TRANSISTOR IGNITION SYSTEM

The transistor ignition system is a relatively new development in battery ignition. It is designed to overcome some of the drawbacks of the conventional ignition system. The output of the conventional ignition is limited to the amount of current in the primary circuit. No more than approximately 5 amperes of current can be carried in the primary circuit without shortening the life of the contact points. This is because the contact points will arc and burn if more current is interrupted. Another factor limiting the output is the length of time the contact points remain closed; and as the engine speed increases, this time becomes increasingly short.



77.158

Figure 7-7.–Spark plug.

The transistor is a device that has the ability to switch large currents through the action of a very small control. The switching action involves no moving parts and is instantaneous when the circuit is designed properly. Conventional contact points turn the transistor on and off at the proper time in relation to the engine timing. A specially designed high-voltage transformer is used instead of the standard ignition coil. This allows the control current to be reduced to 1/2 to 3/4 ampere and still produce 25,000 to 30,000 volts in the secondary circuit. Because of the low current being conducted by the contact points, their life is greatly increased over what they would be in the conventional ignition system.

There are several advantages offered by the transistorized system; for example, extended breaker point life, extended periods between engine tuneups, extended spark plug life, and higher available voltage at the spark plugs.

MAGNETO IGNITION SYSTEM

The magneto used for ignition is usually a self-contained unit. With the exception of the spark plugs and the wires leading to them, the magneto includes or substitutes for all the units usually found in the battery ignition system. The magneto provides electricity for ignition alone and is designed for handcrank starting of the engine. In equipment that requires lights and other electrically operated accessories, the battery ignition system is used. Engines provided with both systems can operate on either system. Should the battery be dead or rundown the engine can run on the magneto alone.

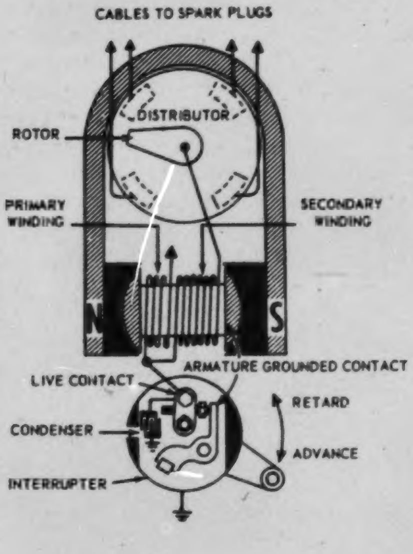
Some magnetos have a permanent magnet and pole pieces to produce a magnetic field. The primary and secondary windings are wound on an armature which rotates within the magnetic field. As the armature revolves, an alternating current of low voltage is generated in the turns of the wire.

When this current reaches its highest value, the breaker points open, and high-tension current is induced in the secondary windings, as in the battery ignition system. The high-tension current is routed to the magneto distributor and to the spark plugs in the proper firing order. The magneto distributor is often a part of the magneto. The magneto, a simple form of electric generator, produces its own current, thus eliminating the need of a battery in the ignition system. See figure 7-8.

IGNITION SYSTEM MAINTENANCE

Aside from a faulty capacitor or ignition coil, most ignition troubles result from loose or broken connections caused by wear during normal engine operation. Unless the engine stops entirely on the job, trouble indications are reported by the vehicle operator and the equipment is held in the shop for repairs.

Unless the trouble is known, a systematic procedure should be followed to locate the cause. Trace the ignition wires for grounds, shorts, and open circuits. Bare wires, loose connections, and corrosion are found through visual inspection. These inspections are easiest and should be made first.



81.140

Figure 7-8.—Circuits of a high tension magneto.

TROUBLESHOOTING

Before making any test, conduct a thorough visual inspection of the ignition system.

BATTERY.—Check terminal posts and cables. Connections must be clean, tight, and free of corrosion.

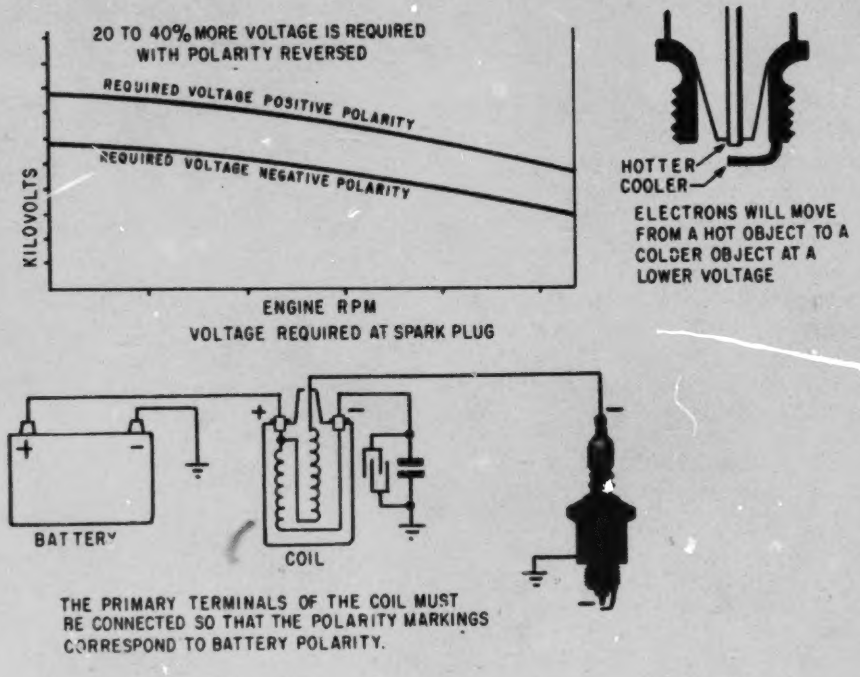
PRIMARY WIRING.—Check for obvious damage such as broken wires, loose wires, frayed insulation, etc. All connections must be clean and tight.

IGNITION COIL.—Pull the high-voltage lead out of the coil tower. Check the tower for signs of corrosion or burning. If it is corroded, clean with a round brush or sandpaper wound around a pencil. Examine the tower carefully for any sign of flashover (high-voltage current leaving the intended path and jumping down, or around, directly to ground). Flashover can be caused by moisture or dirt on the coil exterior, a corroded tower interior, or by failing to have the high voltage lead pushed fully into the tower. If flashover has cracked the tower or left a burned path (carbon track), replace the coil.

Check for correct coil polarity—the coil must be connected into the primary circuit so that the positive and negative markings of the coil correspond to the battery connections. For example, in a negative grounded system, the negative terminal of the coil must be connected to the distributor where it is grounded through the breaker points. By connecting the coil in this manner, the center electrode of the spark plug assumes a negative polarity.

It takes less voltage to cause electrons to move from a hot to a cold surface, and since the center electrode of the plug is always hotter than the side (ground) electrode, current flow must be from the hot center electrode to the cooler side electrode. By giving the center electrode a negative polarity, current will flow in this manner, as shown in figure 7-9.

If the coil is connected so that polarity is reversed (spark plug center electrode positive), up to 40 percent more voltage is required to fire


20 TO 40% MORE VOLTAGE IS REQUIRED WITH POLARITY REVERSED
REQUIRED VOLTAGE POSITIVE POLARITY
REQUIRED VOLTAGE NEGATIVE POLARITY
KILOVOLTS
ENGINE RPM
VOLTAGE REQUIRED AT SPARK PLUG
HOTTER
COOLER
ELECTRONS WILL MOVE FROM A HOT OBJECT TO A COLDER OBJECT AT A LOWER VOLTAGE
+
−
BATTERY
+
−
COIL
−
THE PRIMARY TERMINALS OF THE COIL MUST BE CONNECTED SO THAT THE POLARITY MARKINGS CORRESPOND TO BATTERY POLARITY.

225.86

Figure 7-9.—Correct coil polarity and voltage flow for a negative grounded system.

the plugs. This could result in hard starting, missing, and eventual coil failure. Testing for correct coil polarity with the engine running is covered later in this chapter.

DISTRIBUTOR CAP.—Remove each spark plug lead (one at a time) from the cap. Check for corrosion, signs of burning, or flashover. Corrosion can be removed as previously described for ignition coils. If any sign of flashover is present, replace the cap. When the leads are replaced, ensure they are clean and are fully seated in the towers.

Remove the cap from the distributor and turn it upside down. If signs of burning, cracking, or flashover are present at the center contact or the spark plug terminal posts, the cap must be replaced. Check the spark plug terminal posts and the rotor tip for excessive scoring or burning. Mild scaling, caused by the high voltage jumping from the rotor to the terminal posts, can be removed by lightly scraping the terminal posts.

BREAKER POINTS.—With the ignition switch off, separate the points and check their condition; a dull, slate-gray color is normal. If they have metal transfer (pitting) or are burned, they must be replaced. Breaker points must not be filed to correct pitting.

BREAKER CAM.—If the surface of the cam is rough or pitted, or the cam lobes show excessive wear, the cam must be replaced.

SECONDARY WIRING.—If the spark plug leads are oily or dirty, they must be cleaned. If signs of cracking, swelling, burning, or other damage are present, the leads must be replaced.

After making the visual inspection and correcting any defects that were noted, if the engine is still hard to start or will not start at all, the following tests can be made to locate the defects.

System Tests

Remove the secondary coil lead from the distributor cap and hold it approximately 3/16-inch from ground while cranking the engine, and observe the spark. A bright blue spark indicates proper operation of the primary circuit and the secondary winding of the ignition coil. Troubleshooting can be limited to the distributor cap, rotor, spark plug leads, and spark plugs. A yellow spark indicates that the malfunction is in the primary circuit or the secondary winding of the ignition coil.

PRIMARY CIRCUIT TESTS.–Three basic voltmeter tests can be made to isolate high-resistance areas or components in the primary circuit.

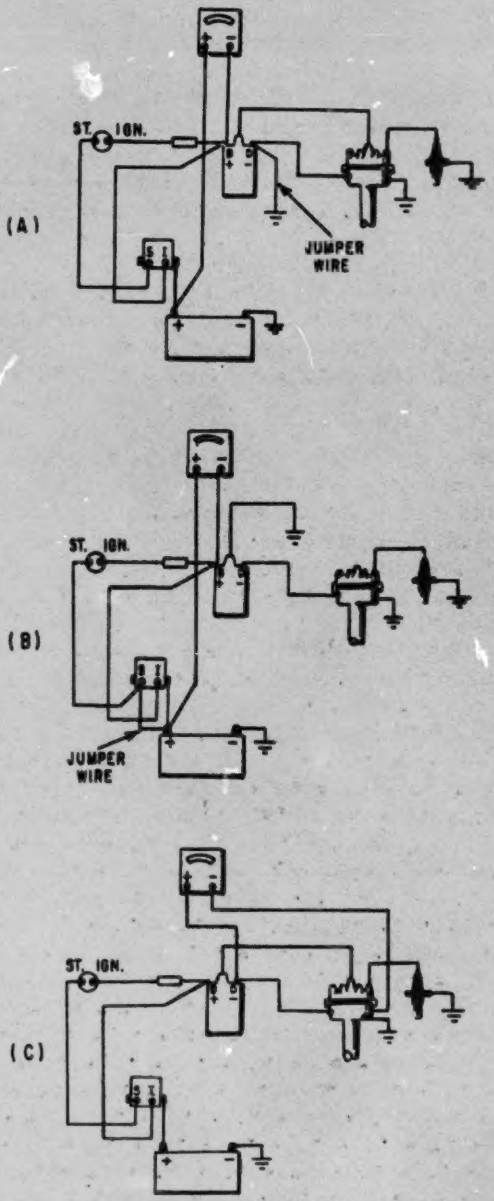
NOTE: The voltage readings and test connections used here are for a representative 12-volt, negative ground system. Always use the test specifications given by the manufacturer for any specific system.

Test 1. Battery to Coil Test.–Connect the voltmeter as shown in figure 7-10(A). Connect a jumper wire from the distributor connection of the coil to ground.

With the ignition switch on and the points closed, voltage drop should not exceed 6.9 volts. If the drop exceeds 6.9 volts, a high resistance exists in the resistor, ignition switch, or the wiring between the battery and the coil. A drop of less than 4.5 volts indicates a shorted resistor.

Test 2. Starting Ignition Circuit Test.–Connect the voltmeter as shown in figure 7-10 (B). Remove the secondary coil wire from the distributor cap and ground the wire.

With the ignition switch off, crank the engine by placing a jumper wire from the battery positive post to the S terminal of the starter solenoid or relay. The voltage drop should not exceed 0.1 volt. If the drop exceeds 0.1 volt, a high resistance exists in the starter solenoid or relay contacts or in the wiring between the starter solenoid or relay and the coil.



225.87

Figure 7-10.–Voltmeter connections for resistance tests of the primary circuit.

Test 3. Coil to Ground Test.—Connect the voltmeter as shown in figure 7-10 (C).

With the ignition switch on and the points closed, the voltage drop should not exceed 0.1 volt. If the drop exceeds 0.1 volt, a high resistance exists either in the coil to distributor wire, the engine to frame ground strap, the distributor to engine mounting, the breaker plate to distributor housing mounting, or in the breaker points.

SECONDARY CIRCUIT TESTS.—If preliminary testing indicates that the malfunction is in the secondary circuit, the defect can be located by making these tests:

Test 1.—Use a megger and, following the instructions provided with it, test the distributor cap, rotor, and spark plug leads for insulation breakdown, cracks, or opens.

Test 2.—Remove and thoroughly examine the spark plugs. Figure 7-11 illustrates some types of fouling and damage that may be encountered.

A plug that exhibits any of the conditions shown in figure 7-11 except F, G, and H, may be reconditioned and reused. Reconditioning is covered later in this chapter. A plug exhibiting any of the conditions in F, G, or H, must be replaced, and the cause for the damage must be corrected.

Repair and Adjustment

The repairs and adjustments that are required on a battery ignition system are comparatively simple to perform, but in order to achieve good equipment performance and economic operation, care must be exercised and correct procedures followed.

DISTRIBUTOR.—Replacement of the breaker points can be accomplished with the distributor installed, but, generally, it is better to remove the distributor from the engine. This not only makes access to the breaker points easier, it also enables the ASM to inspect and, if necessary, repair other components of the distributor.

With the distributor cap removed, scribe a line across the junction of the distributor housing and the engine block, and one on the distributor housing in line with the center of the rotor contact strip. Disconnect the primary lead and, if used, the vacuum advance vacuum line. Remove the distributor holddown bolt and clamp and remove the distributor from the engine.

Clamp the distributor in a soft jawed vise, taking care not to damage the drive gear or housing.

Before attempting to remove the breaker points, with the distributor on or off the engine, stuff small rags in any hole or opening in the breaker plate through which small screws or nuts might fall. Note the location and position of the primary lead-in and condenser wires before disconnecting them.

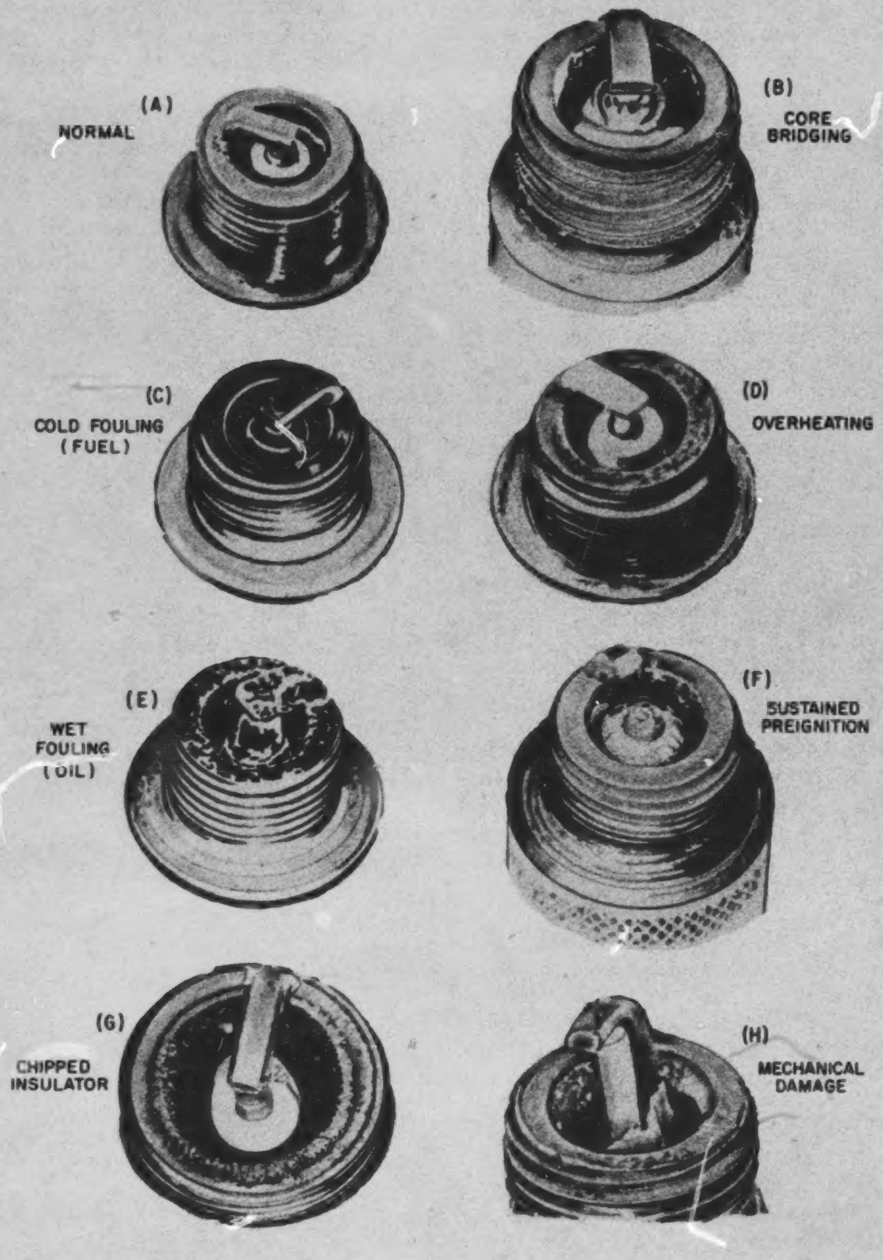
Remove the used points, thoroughly clean the mounting area and the breaker cam, and install the replacement points.

Replacement of the condenser is generally accomplished at the same time the points are replaced. However, if the condenser is to be reused, it should be tested for capacity, resistance, and leakage, using a condenser tester. If a new condenser is used, it should also be tested and the results compared to the manufacturer's specifications for the equipment at hand.

As shown in figure 7-12, a condenser of incorrect capacity will cause heavy arcing across the points, and metal transfer from one contact to the other.

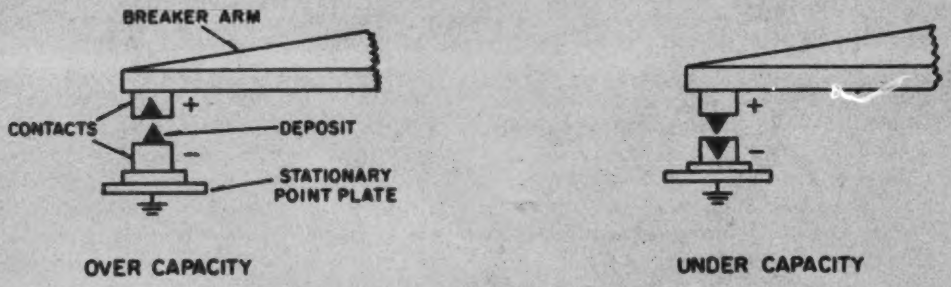
With points and the condenser installed, rotate the breaker cam until the points are closed, and check the alignment of the contacts. If both contacts are flat, the entire surface should contact at the same time. If both contacts are convex, or if one is flat and the other convex, contact should be in the center. If alignment is incorrect, bend the stationary contact bracket to provide correct alignment. Never attempt to align the points by bending the movable arm.

Point gap (amount of opening between the contacts when the points are fully opened by the breaker cam) is critical and must be closely set. If the gap is too small, the points arc and burn; if the gap is excessive, saturation time for the coil is reduced and high-speed missing occurs.


(A)
NORMAL
(B)
CORE
BRIDGING
(C)
COLD FOULING
(FUEL)
(D)
OVERHEATING
(E)
WET
FOULING
(OIL)
(F)
SUSTAINED
PREIGNITION
(G)
CHIPPED
INSULATOR
(H)
MECHANICAL
DAMAGE

225.88

Figure 7-11.—Examples of spark plug appearances.


BREAKER ARM
CONTACTS
+
DEPOSIT
−
STATIONARY POINT PLATE
OVER CAPACITY
+
−
UNDER CAPACITY

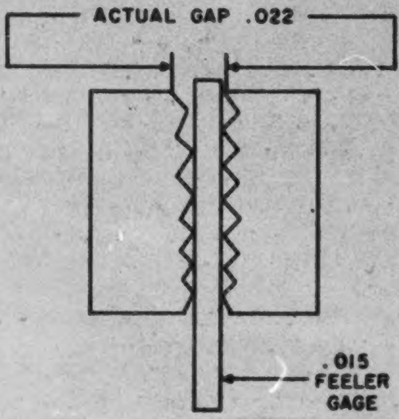
225.89

Figure 7-12.—Effects of incorrect condenser capacity.

The gap for new points may be set initially with a feeler gage. This is done by turning the breaker cam until the point rubbing block is on the highest point of a cam lobe, and moving the stationary point plate until a feeler gage of the correct thickness (refer to manufacturer's specifications) is a snug fit between the contacts.

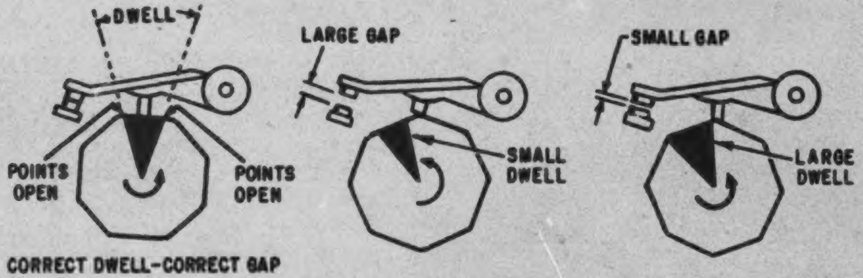
As shown in figure 7-13, used points cannot be gapped accurately with a feeler gage because the gage measures between the high spots while the actual point opening is much greater. Note that a .015 feeler gage is a snug fit, but the actual gap is .022. The correct method of obtaining the necessary accuracy for setting used points is to use a dwell meter.

Dwell, often called cam-angle, refers to the distance, in degrees of breaker cam rotation, that the breaker cam revolves from the time the points close until they are opened again (fig. 7-14.) The dwell for any given set of breaker


ACTUAL GAP .022
.015 FEELER GAGE

225.90

Figure 7-13.—False setting given by feeler gage for used points.


DWELL
POINTS OPEN
POINTS OPEN
CORRECT DWELL–CORRECT GAP
LARGE GAP
SMALL DWELL
SMALL GAP
LARGE DWELL

225.91

Figure 7-14.—Relationship of dwell and point gap.

points is controlled by the point gap, so the two must be considered together.

As can be seen by referring to figure 7-14, if point gap is decreased, dwell increases; if point gap is increased, dwell decreases. Thus, point gap and dwell are indirectly proportional.

Once the point gap has been set, the breaker arm spring tension should be checked using an accurate ounce scale. If the pressure is excessive, rapid wearing of the rubbing block will cause the point gap to narrow, retarding the engine timing and increasing the dwell. Too low a pressure will cause the points to bounce, creating a high-speed miss.

With the rubbing block positioned on the low point between cam lobes, hook the scale at the contact point edge. Pull at right angles to the movable arm and check the pressure just as the points separate, and compare to the manufacturer's specifications. If the pressure is incorrect, refer to the applicable maintenance manual for adjustment procedures. Ensure that all wires are correctly connected and clear of all moving parts. Remove rags that were used to plug openings.

Apply a thin coat of high-temperature grease to the breaker cam. Do not use engine oil or low-temperature grease as it will be thrown off and onto the points. On distributors equipped with a felt wick-type oiler under a lift-off type rotor, moisten with engine oil—3 to 5 drops. Lubricate the point pivot pin and bushing, the centrifugal advance mechanism, and if required, the breaker-plate bearing surfaces very lightly with engine oil. If an outside oiler is provided, apply 5 to 7 drops of engine oil.

CAUTION: Lubricate distributor parts sparingly to avoid getting it on the points because lubricant causes rapid burning of the points.

If a distributor test machine is available, it should be used to check the distributor for dwell, vacuum and centrifugal advance, point bounce, bent shaft, worn bushings, worn breaker cam, etc.

If the distributor was marked before removal, as previously indicated, and the engine has not been cranked since the distributor was removed, installation is simple. Align the rotor with the scribe mark on the distributor housing, align the scribe marks on the housing and engine block, and insert the distributor. As the distributor drive gear meshes with the camshaft gear, the rotor will turn a small amount. Pull the distributor up far enough to disengage the gear and turn the rotor back far enough to compensate for the turning and push down again. When the housing is flush against the block, the scribe lines should be lined up. If they are, install the holddown bolt and clamp, and lock the distributor in place.

If the distributor will not bottom, do not attempt to force it down. The distributor shaft is not aligned with the oil pump shaft slot or tang. Hold firm pressure on the distributor and crank the engine—when the shafts line up, the distributor will drop into place.

If the engine was cranked while the distributor was out, remove the number one spark plug and crank the engine until compression can be felt, and continue to turn the engine until the timing marks (located on the crankshaft vibration dampener or flywheel) are lined up with the stationary pointer. The engine is now ready to fire the number one cylinder. Align the housing-to-block scribe marks and turn the rotor to align with the number one spark plug tower on the distributor cap—points just starting to open. Insert the distributor and, as previously described, pull up and adjust for rotor movement as the gears mesh. When the installation is correct, the distributor will be fully bottomed, points just opening, and the rotor pointing to the number one spark plug tower on the distributor cap. This initial timing setting will suffice for starting the engine.

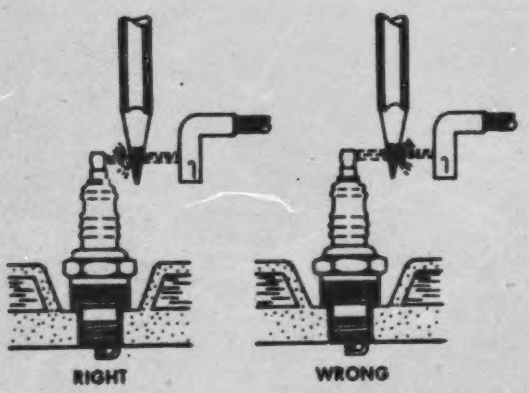
To time the engine to manufacturer's specifications, clean all the grease and dirt from the timing mark and reference pointer. Draw a chalk line over the timing mark to make it more visible. Connect the timing light to the high-tension lead of the No. 1 spark plug and the power leads to the power supply. Connect a tachometer, if available, to the primary circuit of the distributor. Warm the engine to normal operating temperature and adjust the idle speed. Aim the timing light flashes at the timing mark and reference pointer. If the timing mark and pointer do not line up, loosen the distributor and turn it in its mounting until the timing mark does align with the pointer, then secure the distributor. Also check to see if the automatic advance mechanism is working. This is accomplished by keeping the timing light aimed at the timing mark and gradually increasing the engine speed. If the advance mechanism is working, the timing mark should gradually move away from the pointer. If the timing mark fails to move as the engine speed is increased, or if it hesitates and then suddenly jumps, the advance mechanism is not functioning properly and must be repaired.

A quick, simple check for correct coil polarity can be made using an ordinary wooden pencil, as shown in figure 7-15.

Place a piece of rubber hose over the pencil to prevent the possibility of electrical shock. Remove any one of the spark plug wires; place the lead of the pencil between the spark plug wire and the plug. Start the engine and observe the spark—if it flares or has a yellow tinge on the wire side, polarity is reversed; if it flares or has a yellow tinge on the plug side, polarity is correct.

Point gap or dwell must be set before attempting to time the engine, as changing the gap will change the timing.

If used points are to be reused, or the gap setting is to be checked with the distributor installed, connect a dwell meter (following instrument manufacturer's instructions) and, with the engine idling, check the dwell. Compare the dwell reading with the manufacturer's specifications and, if incorrect, the point gap must be adjusted.



224.62
Figure 7-15.—One method of checking coil polarity.

Remove the secondary coil lead from the distributor cap and ground it. Remove the distributor cap and rotor. With the dwell meter connected as before, crank the engine and adjust the points as necessary (while cranking) to obtain the correct dwell. Replace the rotor and distributor cap and reconnect the coil secondary lead. Start the engine and check the dwell—it should not have changed more than 3 degrees. If a greater change is noted, the distributor has worn bearings or a worn cam and should be removed for repair.

SPARK PLUGS.—When plugs receive periodic cleaning and gapping, they will function better and last longer.

Spark plug wires should be carefully removed by grasping them close to their terminals for the pull. Do not "jerk" them from the spark plug terminal. Loosen each plug one or two turns, then use low-pressure compressed air to blow out any dirt around the spark plug hole. This will prevent foreign matter from entering the cylinder.

Remove the plugs, being sure that the gaskets (where used) are also removed. As the plugs are removed, keep them in order so that any peculiar condition of any plug can be related to a specific cylinder.

The plugs shown in figure 7-11 are some examples of plug conditions that may be encountered. The cause for each is discussed below.

(A) is from a mechanically sound engine, running at the correct temperature. Some deposits, light tan or gray in color, are present, but there is no evidence of burning. Some gap growth will have occured, but not in excessive amounts.

(B) is from an engine having excessive combustion chamber deposits that shed off when normal combustion temperature was restored by the installation of new plugs. This is most prevalent in engines operated at slow speeds and in start-stop driving.

(C) is from a cold running engine. The deposits are unburned fuel.

(D) is from an engine that was running too hot due to over-advanced timing, or to cooling system blockage.

(E) is from an engine using excessive amounts of oil. The plug is drowned in oil that is bypassed through the rings or valve guides.

(F) is from an engine that had severe preignition (fuel charge being ignited by an overheated plug, piece of glowing carbon, hot valve edge, etc., before the spark plug fires), and the damage shown resulted from temperatures in the combustion chamber in excess of 2,700° F. The accompanying excessive combustion chamber pressures probably damaged other components of the engine also.

(G) is from an engine that was running normally. The damage was caused by the mechanic attempting to bend the center electrode.

(H) is from an engine which had some foreign object in the combustion chamber.

The plugs shown in (F), (G), and (H), cannot be reused, but the others can be reconditioned.

Before attempting to clean a plug, any oily deposits must be removed with an approved solvent. This is to prevent the cleaning material from being soaked and packed into the area around the center electrode insulator.

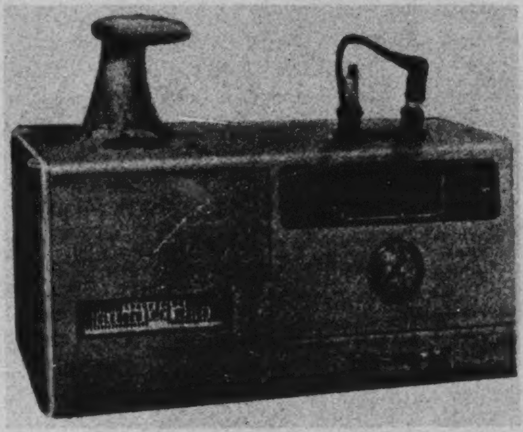
A machine of the type shown in figure 7-16 is used to clean (sand blast) and test the spark plugs.

Following the machine manufacturer's operating instructions, clean the plugs, blasting only long enough to remove the deposits. Prolonged blasting will damage the center electrode insulator.

Once cleaning is completed, the electrodes must be filed clean and square, as the machine blast will not clean this area. If the electrodes are not filed clean, the required voltage will still be high and the plug may misfire.

Using a fine-cut point file, file the end of the center electrode flat. File the side electrode flat and the end square. This produces clean, sharp edges that improve plug performance. Remove only enough metal to clean and square the electrodes.

Using a round wire gage, not a feeler gage, set the gap to manufacturer's specifications by bending the side electrode.



225.92

Figure 7-16.—Spark plug cleaning and testing machine.

Testing spark plugs outside the engine can be very misleading. There is no true relationship between firing a plug in compressed air at room temperature, which is the condition in the testing unit, and firing a plug in an operating engine. In the operating engine, voltages are higher, air-fuel mixtures are present, and the high temperatures in the cylinders aid ignition. If these factors are kept in mind, spark plugs can be successfully tested.

Do not discard plugs which show a bluish light just above the shell while they are being tested. This is a corona discharge caused by the presence of a high-tension field. It does not affect plug performance. Make sure the insulator is clean and dry before testing. If a spark comes through the insulator to the plug shell, it is an indication that the insulator is cracked. Sometimes this crack is hidden inside the shell where it cannot be seen. In many cases, movement of the insulator can be detected by hand pressure.

When replacing plugs, selection of the proper heat range is one of the most important considerations. The spark plug heat range best suited can be found by checking the manufacturer's manual, except in special cases where engine operation is abnormal. In special cases, or when the proper plug cannot be obtained, check with your supervisor to determine which is the best plug available for the particular engine.

Always use new gaskets, if gaskets are required, when installing spark plugs. The gasket performs two important functions–it maintains a gastight seal between the plug and its seat; and most of the heat absorbed by the insulator tip from the burning fuel in the combustion chamber passes through the gasket.

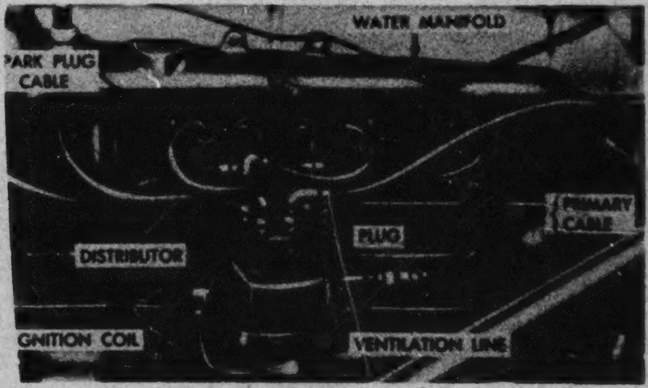
When installing spark plugs, use a torque wrench and tighten them to the torque specified by the engine manufacturer. If the gasket is not tightly seated, the spark plug will become overheated. If the gasket is flattened out too much, the shell may become distorted and damage the insulator.

WATERPROOF IGNITION SYSTEMS

Since many vehicles must operate under very wet conditions, it may be necessary to waterproof the ignition system. Waterproofing means that the system must be so watertight that the components continue to function normally even while totally immersed.

The distributor and ignition coil (fig. 7-17) are sealed in a common housing and enclosed by a common cover. This unit also has a means of ventilating the distributor, thus preventing condensation and the formation of harmful chemicals. Ventilation is accomplished by connecting two tubes to the distributor, one leading to the air cleaner (from which clean air can be obtained) and the other to the intake manifold. The intake manifold vacuum causes air to pass through the distributor from the air cleaner, thus keeping the distributor well ventilated.

The various leads in the ignition system are enclosed in a watertight conduit. This conduit prevents moisture from getting to the leads, thus preventing insulation deterioration from this cause. Repair and maintenance of waterproof ignition systems is similar to that on conventional systems. The same tests and checks should be made, but in most cases special adapters for use on the waterproof connections are furnished with the test equipment. When replacing any connection on the waterproof system, make sure the gaskets and seals are in good condition, and that waterproof integrity is maintained.



81.141

Figure 7-17.—Waterproof ignition system.

AUTOMOTIVE ELECTRICAL SYSTEM

LIGHTING SYSTEM

The lighting system of automotive vehicles includes the headlights, taillights, instrument lights, the signal and warning lights, directional signals, electrical wires and cables, and the source of electricity (battery or generator). The equipment is provided with the electrical system required for the job the equipment is designed to accomplish. The most important basic units of the lighting circuits are the lamps (lights), switches, and fuses or circuit breakers.

Lamps and Bulbs

Light bulbs used in automotive vehicles are made to operate on 6 or 12 volts, depending on the voltage of the system used. The bulbs have a filament that becomes incandescent when the electric current passes through it. Bulbs are rated as to size by the candlepower of light they produce. The greater the candlepower of the bulb, the more current it requires when lighted. These ratings are found on the shell of the base of the bulb.

When the light bulbs are replaced in a vehicle, be sure the new bulbs are of the proper rating. With the exception of the sealed beam headlights, the other bulbs within the vehicle will be of the single or double contact type.

Sealed Beam Headlights

Most vehicles have sealed beam headlights, which are far superior to the older type headlights. Not only does the sealed beam light provide far better and more powerful illumination that earlier model lamps, but it maintains its initial brilliancy with only a slight loss throughout its life. This is because the lens is permanently sealed to the reflector which effectively bars moisture (which corrodes the reflector) and prevents the entrance of dust and dirt.

When a filament burns out, the whole unit must be replaced. However, it has a greater filament life than other type of lamps and requires no maintenance to keep in good condition.

Miscellaneous Lights

Ordinarily, indirect lighting is used for the instrument lamps, which light whenever the light switch is ON. Many vehicles are equipped with a switch that controls only the instrument lights so they can be turned on or off when desired.

Smaller lights used for parking are often located immediately above or below the headlights. Side lights sometimes serve as parking lights.

Taillights and stoplights are ordinarily combined and contained in a single housing with red lens. A larger lamp (about 15 candlepower) is used for the stoplight and a smaller lamp (about 3 candlepower) is used for the taillight. Taillights and stoplights are sometimes enclosed in a single lamp having a double filament. Taillights light whenever the lighting switch is in any of the ON positions.

When the backup lights are present, they are mounted so as to direct the light to the rear of the vehicle. They are wired so that the lamp is lighted whenever the shift control is put in the reverse position.

Directional signal lights, present on self-propelled automotive equipment, have the purpose of conveying the operator's intentions to turn, by a flashing signal. A lever in the driver's compartment activates the direction signals. Another switch activates all the directional lights, giving off a flashing signal, to warn of an emergency or of the presence of the vehicle.

Circuit Breakers, Switches, and Fuses

Most switches are placed on the instrument panel close to the driver or operator, and the fuses or curcuit breakers can usually be found behind the instrument panel on a fuse block. The light control switch of the push-pull type is a common type and usually controls three circuits. Should such a switch be replaced, be sure to tag the wires before removing them or change them from the old to the new switch one at a time. Removing the grounded battery terminal before changing the switch will prevent blowing the fuses.

Light switches are placed between the source of the current and the light bulb in series with the circuit they control. Be sure the light switch terminals are not grounded to any part of the frame or body to which they are fastened for support. If grounded, the lights in the circuit will not burn. Stoplight switches, in which the contacts close automatically when the brake pedal is depressed, are subject to grounding. Being fastened to the underpart of most vehicles, they are easily grounded by water splashed up from the roadbed and must be replaced. Before replacing any light switches, be sure the lights which are controlled by the switch are properly grounded. Poor ground connections caused by rust and corrosion are responsible for many troubles in lighting systems.

Fuses are placed in electrical circuits to protect wires and electrical units from a heavy flow of current. Each circuit, or at least each individual electrical system, is provided with a fuse that has an ampere rating equal to the maximum current required to operate the units. The fuse is made from a metal with a low melting point and forms the weakest point of the electrical circuit. In case of a short circuit or other trouble, the fuse will be burned out first and will open the circuit just as a switch would do. When a fuse is replaced, be sure that it has a rating equal to the one burned out and that the trouble that caused the failure has been repaired.

Wiring Systems

Locating electrical troubles is the largest task in wiring, maintaining, and repairing electrical systems. When the lights fail or the starter becomes inoperative, the trouble cannot always be found in a dead battery or a faulty generator. The trouble may be due to other causes, usually bare wires or poor connections.

Each piece of automotive equipment is provided with an operation and maintenance manual. The manual contains wiring diagrams, which will aid in troubleshooting and repairing electrical systems. The diagrams show how the electrical units in the equipment are connected and the location of fuses and switches. Since the ASE has the responsibility for repair of the electrical system, detailed information is not given in this manual.

SAFETY

Electric shock may cause unconsciousness, stoppage of breathing, burns of all degrees, and instant death. If a current of 60-Hz ac were passed through a person from hand to hand or hand to foot, the effects of 0.1 ampere for 1 second would be fatal. You must understand and remember that current (amperes) is the shock factor rather than the amount of voltage.

When any electrical equipment is to be repaired, the main switches should be in the open position or the battery cable should be disconnected. They should be tagged to read that the circuit is broken for repair purposes. The circuit should not be closed except by the person who affixed the tag and only after the work is completed.

Fuses should be removed and replaced only when the circuit is deenergized. When a fuse burns out, it should be replaced only with a fuse of the same current and voltage rating. Since the burned out fuse is often an indication of a faulty circuit, the circuit should be carefully checked before making the replacement.

Personnel should never work alone on high-voltage circuits. The tools used on these circuits should have rubber insulation on their handles. Do not work on any type of electrical apparatus with wet hands or while wearing wet clothing. Safety shoes with nonconducting soles should be worn.

Repair work on energized circuits should not be undertaken except in emergencies. When it is necessary, ample light should be provided and the worker should be insulated from ground with a nonconducting material such as dry wood or rubber matting. The worker should use only one hand to work on the circuit and keep the other hand away from the energized circuit.

Navy specifications for portable tools require that the electric cord for such tools be provided with a distinctively marked ground wire in addition to the conductors for supplying power to the tool. One end of the ground wire must be connected to the tool housing and the other end must be connected to ground. Specially designed ground-type plugs and receptacles that automatically make this connection when the plug is inserted in the receptacle must be used.

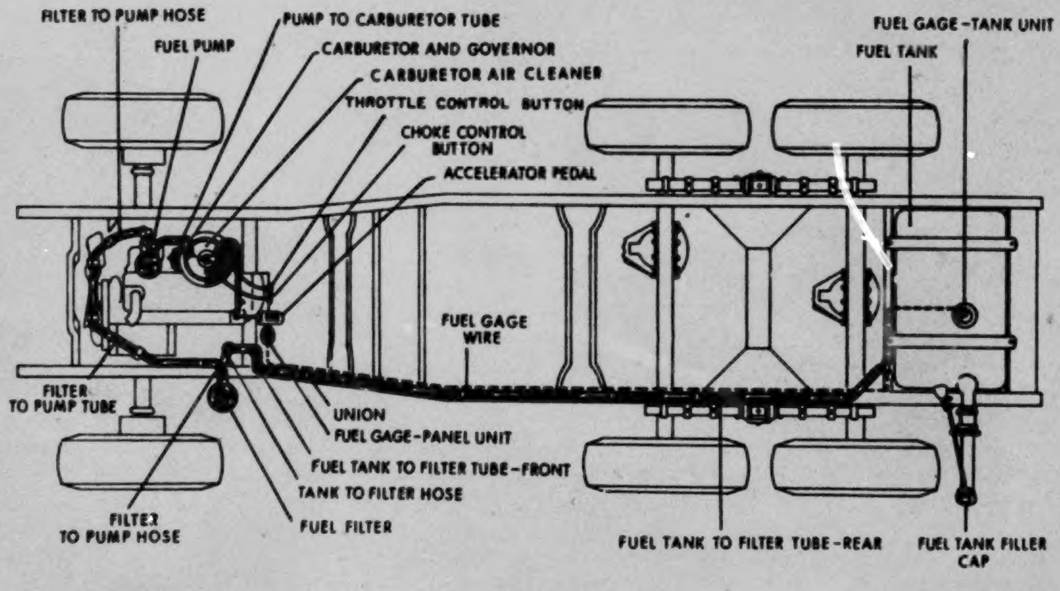
The principal hazard in working with and around batteries is the danger of acid burns from spillage of the electrolyte. Proper care in filling and handling batteries will eliminate this danger. Eyeshields, rubber gloves, rubber aprons, and rubber boots with nonskid soles should be worn when batteries are being refilled. Eyeshields should be worn when working around a battery to prevent any possibility of acid burns to the eyes.

There is danger of explosion from the hydrogen gas that is given off when batteries are charged. The charging should take place outside or in a well-ventilated room. No open flame should be permitted near the charging operation. Caution should be taken to prevent any spark near a battery at any time.

FUEL SYSTEM

The fuel system (fig. 7-18) consists of a fuel tank, fuel pump, carburetor, intake manifold, and fuel lines or tubes, connecting the tank, pump, and carburetor.

The fuel system supplies to the engine cylinders a combustible mixture of gasoline and air. It stores the gasoline in liquid form in a fuel tank, then converts this liquid into a vapor and mixes it with air. The mixture enters the engine cylinders on the intake strokes; it is then compressed and ignited. In burning, the fuel-air mixture increases in temperature, which causes it to expand, and a high pressure is therefore produced in the engine cylinders. This pressure forces the pistons downward on the power strokes. The fuel system must vary the proportions of air and gasoline for different operating conditions. For normal running with a warm engine, the proper mixture ratio is about 15 pounds of air to 1 pound of gasoline. But for initial starting with a cold engine, a much richer mixture is needed; the mixture does not burn as


FILTER TO PUMP HOSE
FUEL PUMP
PUMP TO CARBURETOR TUBE
CARBURETOR AND GOVERNOR
CARBURETOR AIR CLEANER
THROTTLE CONTROL BUTTON
CHOKE CONTROL BUTTON
ACCELERATOR PEDAL
FUEL GAGE-TANK UNIT
FUEL TANK
FUEL GAGE WIRE
FILTER TO PUMP TUBE
UNION
FUEL GAGE-PANEL UNIT
FUEL TANK TO FILTER TUBE-FRONT
TANK TO FILTER HOSE
FUEL FILTER
FILTER TO PUMP HOSE
FUEL TANK TO FILTER TUBE-REAR
FUEL TANK FILLER CAP

81.75

Figure 7-18.—Fuel system for a gasoline engine.

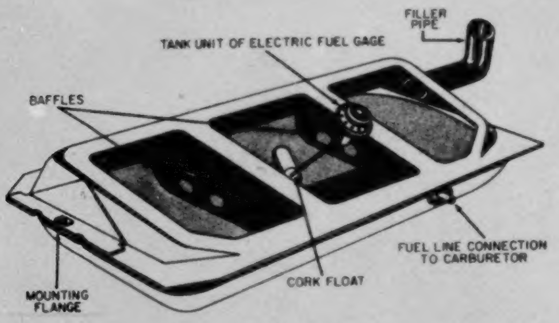
readily in a cold engine, and the gasoline does not turn to vapor so readily. Also, when accelerating, or during high-speed or full-load operation, a richer mixture is required. Richness here means a higher proportion of gasoline; a mixture of 9 pounds of air to 1 pound of gasoline would be a rich mixture. The opposite of richness is leanness. A 15 to 1 mixture ratio would be a relatively lean mixture.

Some gasoline engines use a fuel-injection fuel system. With the injector system, a pump delivers fuel to a fuel injector. The injector then injects the proper amount of fuel into the intake manifold during the intake stroke.

STORAGE

On passenger vehicles the fuel tank is generally mounted in the rear of the chassis. On trucks it is generally installed under or behind the driver's seat or behind or to the side of the cab.

Figure 7-19 illustrates the general construction of a fuel tank. Most fuel tanks are of similar construction. They are usually made of thin-gage tinned metal and have an inlet or filler pipe and an outlet. The outlet, with a fitting for the fuel line connection, may be in the top or side of the tank. The lower end of the outlet pipe is placed about one-half inch from the bottom of the tank so that any sediment which collects in the tank will not be carried to the carburetor. Baffle plates may be placed inside the tank to reinforce the sides and bottom and to prevent the fuel from surging or splashing. A drain plug is placed in the bottom so that the tank can be drained and cleaned. The fuel tank must be equipped with an air vent. This vent is usually located in the cap of the inlet pipe.


FILLER PIPE
TANK UNIT OF ELECTRIC FUEL GAGE
BAFFLES
FUEL LINE CONNECTION TO CARBURETOR
CORK FLOAT
MOUNTING FLANGE

81.76

Figure 7-19.—Fuel tank with top cut away.

Some vehicles, especially heavy duty ones, have more than one tank. On these the auxiliary tanks are interconnected, and each has a shutoff valve, so that the flow of fuel from one or more of the tanks may be turned off.

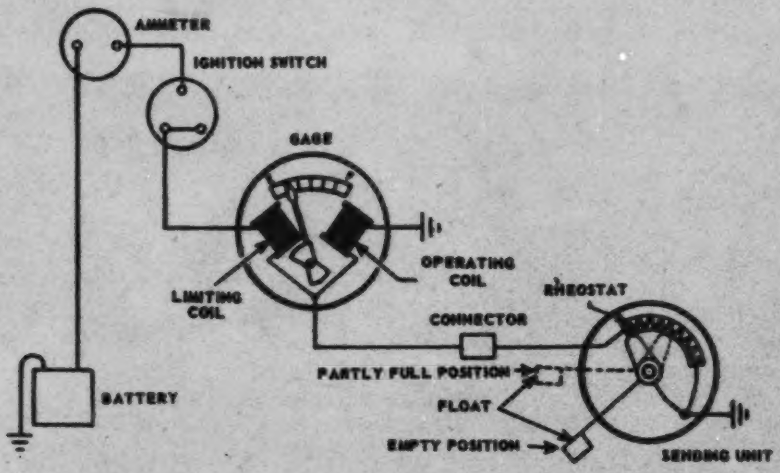
Fuel tanks give little or no trouble, and as a rule require no servicing other than an occasional draining and cleaning. However, if they are punctured or develop leaks, they should not be welded or repaired with or near an open flame until all traces of fuel and fuel vapors have been completely removed from the tank.

The fuel GAGE is a signaling system which indicates the amount of fuel in the tank. Most fuel gages are electrically operated and are composed of two units: the gage itself, which is mounted on the instrument panel of the vehicle; and the sending unit, which is mounted on the fuel tank.

An electrical fuel gage normally operates only when the ignition switch is turned on. There are two types of electrically operated gages: the balance coil and the thermostatic.

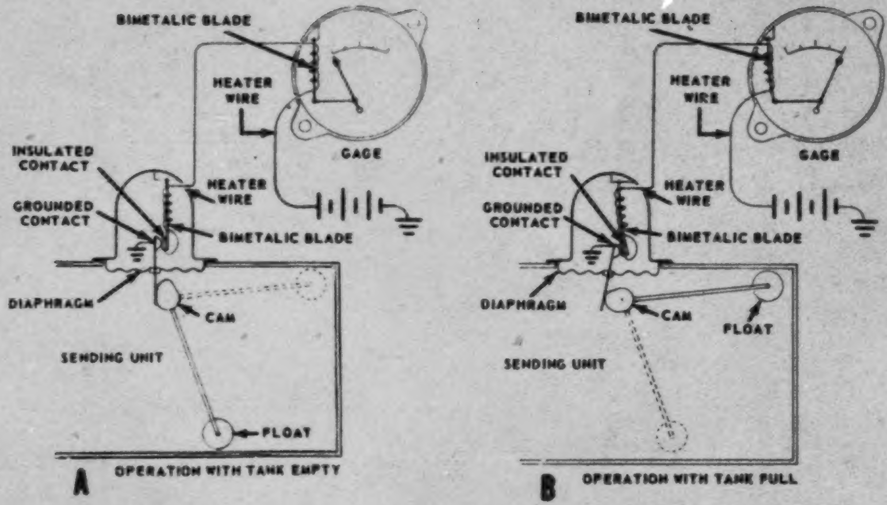
The tank unit of the balancing coil type of fuel gage has a float and arm assembly connected to a sliding contact. See Fig. 7-20. As the fuel level in the tank changes, the position of the contact changes on a rheostat winding thus varying circuit resistance and resulting current flow. The unit on the instrument panel contains two magnetic coils (limiting coil and operating coil), and a permanent magnet which is attached to the gage needle. When the fuel tank is empty, the limiting coil is stronger than the operating coil; thus the magnet is drawn toward it and the needle reads at "E" (empty) on the gage. As the tank is filled, the operating coil becomes stronger, attracting the magnet and moving the needle toward the "F" (full) position.

The thermostatic gage operates by the heating of bimetallic thermostatic blades which are located in the sending unit and in the gage. See fig. 7-21. When the tank is empty, the two contacts in the sending unit are just touching


AMMETER
IGNITION SWITCH
GAGE
OPERATING COIL
LIMITING COIL
RHEOSTAT
CONNECTOR
PARTLY FULL POSITION
FLOAT
BATTERY
EMPTY POSITION
SENDING UNIT

81.77

Figure 7-20.—Coil-type gage circuit.


BIMETALIC BLADE
HEATER WIRE
GAGE
INSULATED CONTACT
HEATER WIRE
GROUNDED CONTACT
BIMETALIC BLADE
DIAPHRAGM
CAM
SENDING UNIT
FLOAT
A
OPERATION WITH TANK EMPTY
BIMETALIC BLADE
HEATER WIRE
GAGE
INSULATED CONTACT
HEATER WIRE
GROUNDED CONTACT
BIMETALIC BLADE
DIAPHRAGM
CAM
FLOAT
SENDING UNIT
B
OPERATION WITH TANK FULL

81.78

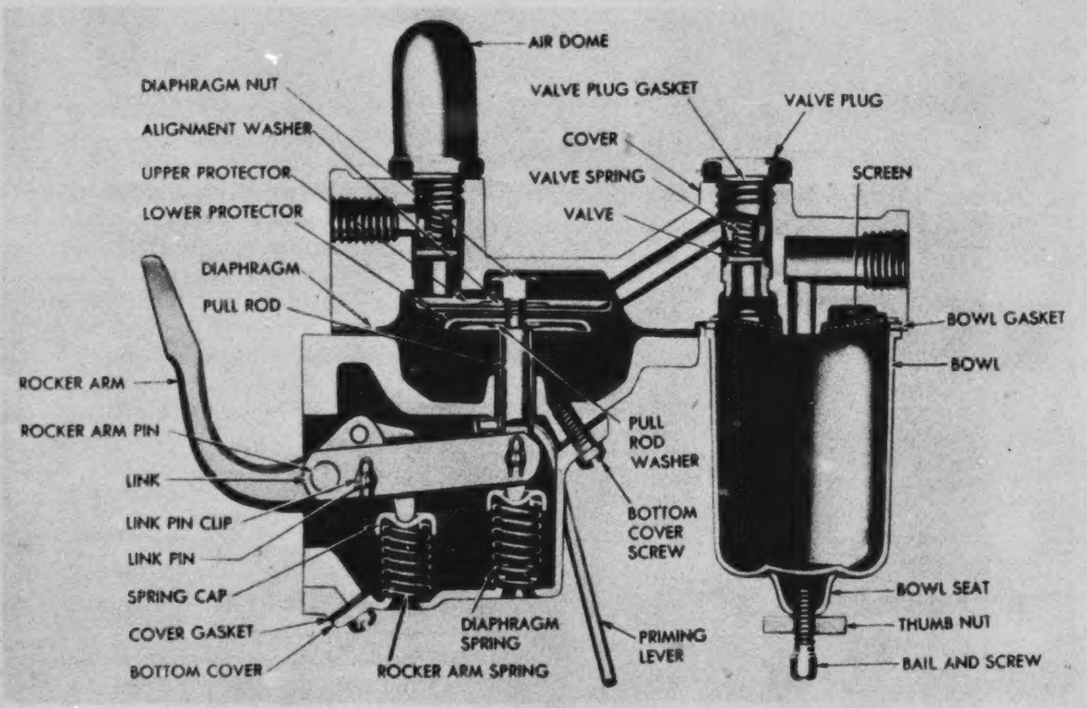
Figure 7-21.—Wiring circuit for thermostatic-type fuel gage.

each other. Current flows through the resistance heater wires of both gage and sending units, causing the bimetallic blades to bend. Bending of the blade in the sending unit separates the contacts to break the circuit. The heater wire cools when the current stops flowing, and the bimetallic blades return to their original position. Contact is again made, and the cycle of operation is repeated approximately every second. Opening and closing of the contacts give an intermittent flow of current which does not heat the gage blade enough to bend it. The blade then holds the pointer at the empty reading. When the tank is full, the float is at the top. In this position, the cam pushes the grounded contact against the insulated bimetallic contact, bending the bimetallic blade in the sending unit. Since the blade is then under a strain, the current must flow longer to bend it enough to open the contacts. The longer flow of current will then cause a bending of the bimetallic blade in the gage unit; the bending of the blade forces the pointer over to the full position.

FILTER

The purpose of the filter is to remove dirt and foreign matter from the gasoline. The filter may be located between the tank and fuel pump or between the fuel pump and carburetor. The filter (fig. 7-22) is an integral part of the fuel pump. In a pump of this type, fuel enters the glass bowl and passes up through the filter screen before flowing through the outlet. Any water or dirt caught by the screen falls to the bottom of the bowl, from which it can be removed.

Another type of filter is made of a series of laminated discs placed within a large bowl which acts as a settling chamber for the fuel and


AIR DOME
DIAPHRAGM NUT
VALVE PLUG GASKET
VALVE PLUG
ALIGNMENT WASHER
COVER
UPPER PROTECTOR
VALVE SPRING
SCREEN
LOWER PROTECTOR
VALVE
DIAPHRAGM
PULL ROD
BOWL GASKET
BOWL
ROCKER ARM
ROCKER ARM PIN
PULL ROD WASHER
LINK
LINK PIN CLIP
BOTTOM COVER SCREW
LINK PIN
SPRING CAP
BOWL SEAT
COVER GASKET
DIAPHRAGM SPRING
PRIMING LEVER
THUMB NUT
BOTTOM COVER
ROCKER ARM SPRING
BAIL AND SCREW

81.79

Figure 7-22.—Cross section of a fuel pump with a filter bowl.

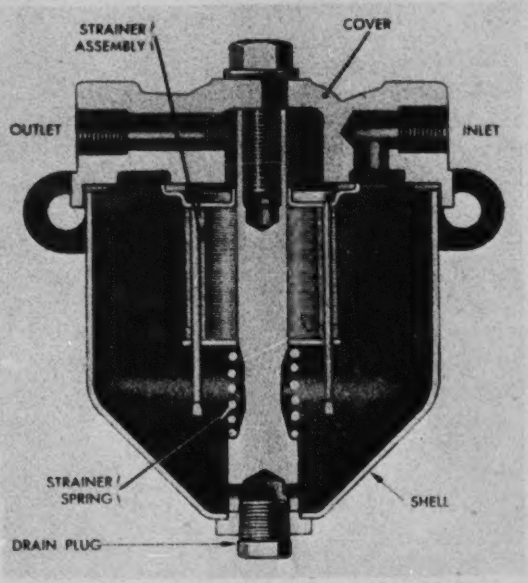
encloses the discs or strainer assembly (fig. 7-23). Some commercial-type vehicles use filters with ceramic elements. The metal disc is the type commonly used in Navy vehicles.

PUMP

A fuel pump delivers the fuel requirements of the engine under all operating conditions. The fuel is pumped from the tank to the carburetor. Figure 7-22 shows a sectional view of a typical fuel pump.

Not only must the fuel pump deliver enough fuel to supply the requirements of the engine, but it must also maintain a proper pressure in the line between the fuel pump and the carburetor.

Excessive fuel-pump pressure holds the carburetor float needle off its seat, causing a high gasoline level in the float chamber, which in turn increases gasoline consumption. Too low a fuel-pump pressure may cause an insufficient fuel flow into the carburetor and cause air locks to occur in the fuel lines. Air in the fuel line will interrupt the flow of fuel to the carburetor resulting in engine power loss or operation failure. The average fuel-pump operating pressure will vary from 3 to 5 psi. The pump should be tested periodically to ensure proper operating pressure.



81.80

Figure 7-23.—Fuel filter.

During the suction stroke of a mechanical fuel pump, the rotation of an eccentric on the camshaft moves the pump operating arm which pulls the diaphragm lever and the diaphragm downward. This downward motion against the pressure of the diaphragm spring produces a vacuum in the pump chamber. The vacuum holds the outlet valve closed, pulls the inlet valve open, and draws the fuel from the supply tank. The fuel flows through the inlet, up through the filter screen, and down through the inlet valve into the pump chamber. During the return stroke, the diaphragm is forced up by the diaphragm spring, the inlet valve closes, and the outlet valve is forced open. This action allows the fuel to flow through the outlet to the carburetor.

The diaphragm operating lever is hinged to the pump arm at the arm pivot so that it can be moved down but cannot be raised by the pump arm. The pump arm spring makes the arm follow the cam without moving the lever. The lever is moved upward only by the diaphragm spring. The pump, therefore, delivers fuel to the carburetor only when the fuel pressure in the outlet is less than the pressure maintained by the diaphragm spring. This condition arises when the fuel passage from the pump into the carburetor float chamber is open and the float needle valve is not seated. The carburetor float and needle valve control the fuel level in the carburetor. The dome-shaped air chamber is added to the pump to smooth out the pulsation (surging) of fuel being pumped.

Fuel pumps are classified as positive and nonpositive diaphragm. The positive type continues to pump fuel even when the carburetor bowl is filled and requires a method of bypassing the fuel back to the tank. The nonpositive diaphragm pump is the one usually found in the gasoline engine. It delivers fuel to the carburetor only when it is needed for the requirements of the engine. The diaphragm in this pump is a vibrating disc that causes the pumping action.

The single action pump, such as that just described, may be actuated mechanically. But some, especially on large engines, operate electrically. Such pumps contain a flexible metal bellows operated by an electromagnet. As the bellows expands, fuel from the tank enters through the inlet valve. When the bellows collapses, the fuel is forced through the outlet valve and to the carburetor. A few electrically operated fuel pumps function with an electric motor, which is installed in a fuel pump housing in the bottom of the fuel tank, or externally from the fuel tank.

Repair kits are provided for overhauling fuel pumps. The diaphragm, composed of several layers of specially treated cloth which is not affected by gasoline, will wear and need replacing. Excessive wear in the operating linkages will prevent proper pumping action. New diaphragms, replacement parts, and small washer and springs needed for the valves, will be found in the repair kits.

A pump action tester or analyzer will show whether the amount of fuel pumped is sufficient for smooth engine operation. If an analyzer is not available, remove the pump from the engine and install a rubber hose on the inlet and another rubber hose on the outlet of the pump. Place the end of the inlet hose in a container of gasoline. Move the lever or rocker arm in and out, watching whether the flow of gasoline at the outlet hose is free and sufficient.

Some pumps have vacuum boosters (fig. 7-24) built into them to provide for positive operation of the windshield wiper at all times. These boosters overcome any failure of the wipers on acceleration and on full throttle. They operate the wipers only when the manifold vacuum itself is not sufficient to maintain action. The booster unit diaphragm is pushed up when the rotation of the camshaft eccentric moves the rocker arm and expels air through the exhaust valve. On the return stroke of the rocker arm, a spring moves the diaphragm down,

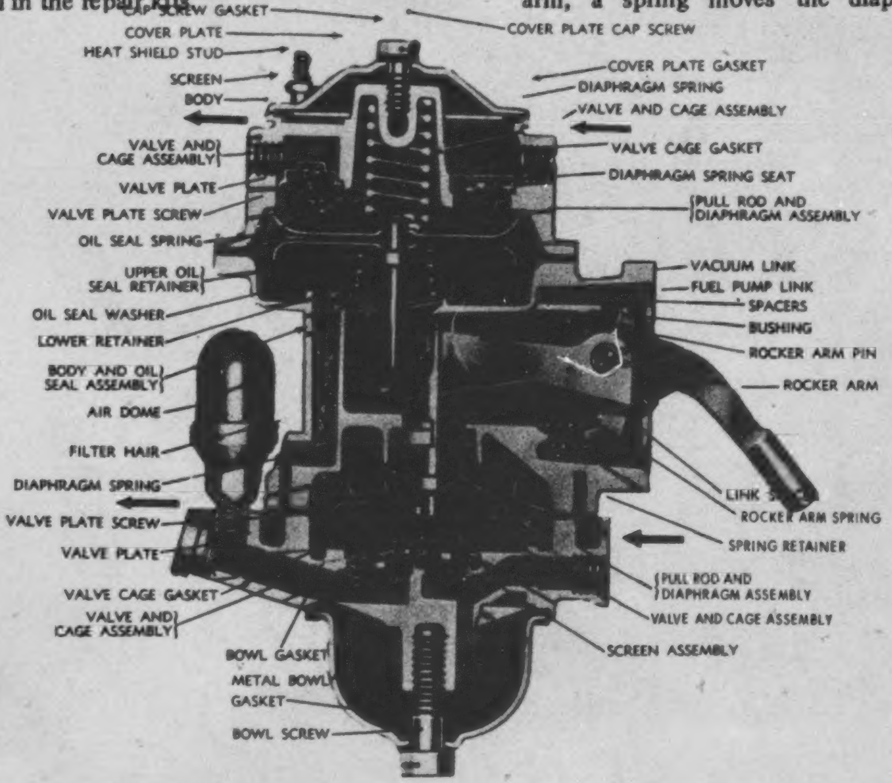

CAP SCREW GASKET
COVER PLATE
HEAT SHIELD STUD
SCREEN
BODY
VALVE AND CAGE ASSEMBLY
VALVE PLATE
VALVE PLATE SCREW
OIL SEAL SPRING
UPPER OIL SEAL RETAINER
OIL SEAL WASHER
LOWER RETAINER
BODY AND OIL SEAL ASSEMBLY
AIR DOME
FILTER HAIR
DIAPHRAGM SPRING
VALVE PLATE SCREW
VALVE PLATE
VALVE CAGE GASKET
VALVE AND CAGE ASSEMBLY
BOWL GASKET
METAL BOWL
GASKET
BOWL SCREW
COVER PLATE CAP SCREW
COVER PLATE GASKET
DIAPHRAGM SPRING
VALVE AND CAGE ASSEMBLY
VALVE CAGE GASKET
DIAPHRAGM SPRING SEAT
PULL ROD AND DIAPHRAGM ASSEMBLY
VACUUM LINK
FUEL PUMP LINK
SPACERS
BUSHING
ROCKER ARM PIN
ROCKER ARM
LINK
ROCKER ARM SPRING
SPRING RETAINER
PULL ROD AND DIAPHRAGM ASSEMBLY
VALVE AND CAGE ASSEMBLY
SCREEN ASSEMBLY

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Figure 7-24.—Fuel pump with vacuum booster.

creating a vacuum in the pump chamber. This vacuum keeps the windshield wipers operating normally when the throttle is wide open. When the wipers are not being used, the vacuum holds the diaphragm up against spring pressure so that it is not fully pushed up at each rocker arm movement.

Several types of electric pumps are used. One type, the Autopulse, makes use of a metal bellows which is expanded by a solenoid when the unit is turned on. This action draws gasoline from the fuel tank into the bellows. As the bellows reaches its limit of expansion, electrical contacts in the solenoid are tripped open and the solenoid releases the bellows. This contraction closes the intake valve in the pump and opens the outlet valve. Gasoline in the bellows is forced through the outlet valve to the carburetor.

A second type of electrical fuel pump is operated by an electric motor. The complete assembly is installed in a fuel pump housing in the fuel tank. The motor, as it runs, drives a pair of gears or a small impeller that pumps the fuel to the carburetor.

Fuel lines connecting the various units of the fuel system are usually made of drawn-copper tubing. However, copper tubing is being replaced by rolled-steel tubing which is rust-proofed by copper or zinc plating. You can learn about cutting and fitting tubing in *Tools and Their Uses,* NAVEDTRA 10085 (Series). Three kinds of fittings are shown in figure 7-25. These are the flared, compression, and soldered types. Of the three, the flared fitting is most common.

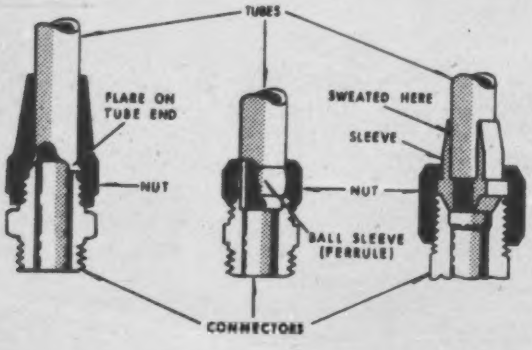

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Figure 7-25.—Types of fittings used on fuel lines.

Fuel lines are placed away from exhaust pipes, mufflers, and manifolds so that excessive heat will not cause vaporlocks. They are attached to the frame, engine, and other units so that the effects of vibration will be minimized. Fuel lines should be free of contact with sharp edges which might cause wear. In places of excessive movement, as between a vehicle frame and rubber-mounted engine, short lengths of gasoline-resistant flexible tubing are used. Occasionally, road vibration may loosen and break the lines, or they could become pinched or flattened by flying rocks. Such damage could interfere with the flow of the fuel.

A certain amount of scale forms within the line tubes and sometimes causes a stoppage. If this condition occurs, blow the tubes clear with low-pressure compressed air.

CARBURETOR

The principles of carburetion will be discussed here so that trainees may better understand the workings of a carburetor and how the other components of the fuel system function to provide a combustible mixture of fuel and air to the engine cylinders.

Air is composed of various gases, mostly nitrogen and oxygen. These gases are, in turn, made up of tiny particles called molecules. All substances, whether solid, liquid, or gas, are made up of molecules. In solids, such as ice or iron, the particles are held very closely together so that they seem to have no motion. In liquids, the molecules are not held together so tightly, so they can move with respect to each other. In gases, there is still less tendency for the molecules to hold together and the molecules can therefore move quite freely. The molecules of a gas are attracted to the earth by gravity, or by their weight. It is the combined weight of the countless molecules in the air that make up atmospheric pressure.

When a liquid changes to a vapor, it has evaporated. When this happens, molecules of the liquid move from the liquid into the air. As this continues, the liquid disappears from its container and appears as vapor in the air. The rapidity of evaporation varies with a number of factors. One of these is the volatility of the liquid. Others include temperature, total pressure above the liquid, and amount of liquid that has already evaporated into the air above the liquid.

When a substance is heated the molecules move faster. This is true regardless of whether the molecules are in a solid, liquid, or gas form. In other words, the rate of evaporation increases with increased temperature. This action can be seen in the process of boiling water.

When there is little gas (atmospheric) pressure above the liquid, the molecules can escape from the liquid more easily than when the pressure is high. This is to say that liquid in a partial vacuum will evaporate more rapidly than the same liquid under pressure.

If the evaporation is taking place in a closed chamber, as for instance in a jar, evaporation of the liquid will soon stop; the closed space above the liquid will soon become "filled" with escaped molecules. These escaped molecules are in motion, just as all other molecules are moving. Some of the escaped molecules will be knocked back into the liquid. This action balances the escapes so that for every molecule that leaves the liquid, a molecule will reenter the liquid. As a result, a state of balance exists and evaporation can be said to have stopped.

Volatility refers to the ease with which a liquid vaporizes. A highly volatile liquid evaporates very rapidly. A liquid of low volatility evaporates slowly. Gasoline is a mixture of several different fuels with varying degrees of volatility.

Atomization means breaking a liquid into very tiny particles or globules. Atomization helps to turn a liquid into a vapor. If a spoonful of gasoline is put into a pan, several seconds are required for it to evaporate, the length of time depending on temperature, volatility, and pressure. However, if this spoonful of gasoline is put into an ordinary spray gun (fig. 7-26) the gasoline is broken into a fine mist when the gun is operated, and this mist turns almost instantly into vapor. The reason for this is that a much greater area of the liquid is exposed to air when the gasoline is atomized. Evaporation takes place from all surfaces and increases with greater surface area.

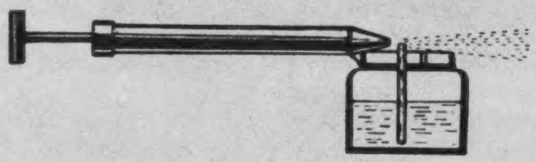
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Figure 7-26.—Spray gun.

A venturi is an hourglass-shaped restriction. In the carburetor (fig. 7-27) a venturi is placed in the air horn through which the air must pass on its way to the intake manifold and the engine cylinders. The purpose of the venturi is to create a partial vacuum (pressure less than atmospheric) at the outlet of the nozzle. This will permit the atmospheric pressure on the surface of the gasoline in the float bowl to force the gasoline out through the nozzle. This gasoline then sprays and atomizes in the passing air to form the fuel-air mixture.

Venturi action and the basic principles of carburetion have just been discussed. Several controls and circuits must be added to the simplified carburetor shown in figure 7-27 for it

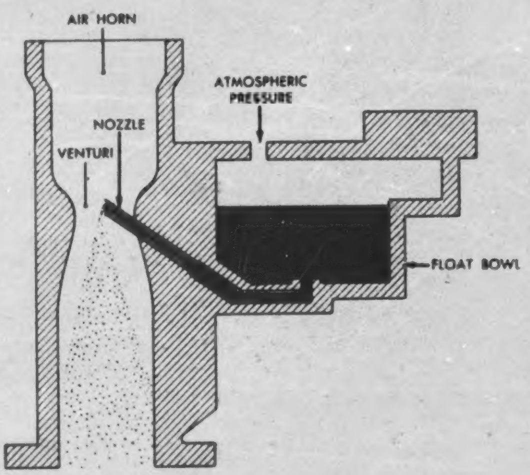

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Figure 7-27.—Simplified carburetor.

to vary the fuel-air ratio for different operating conditions. These controls and circuits include the accelerating system, which momentarily enriches the mixture for improved acceleration when the throttle is opened; the maximum power circuit, which enriches the mixture when the throttle is opened wide for high-speed or full-speed operation; the float system, for keeping a constant level of gasoline in the carburetor bowl; the idling circuit, for supplying an enriched mixture during engine idling.

Throttle

The throttle is a device in the carburetor that is used to vary the amount of fuel-air mixture that enters the intake manifold. This is necessary so the speed of the engine can be changed. The throttle valve (fig. 7-28) is simply a round disc mounted on a shaft so it can be tilted at various angles in the carburetor throttle valve body. When it is parallel to the airflow, it offers almost no restriction and a full volume of fuel-air mixture can pass into the intake manifold. The throttle valve is connected by a linkage to the throttle control (accelerator pedal and hand throttle) in the driver's compartment.

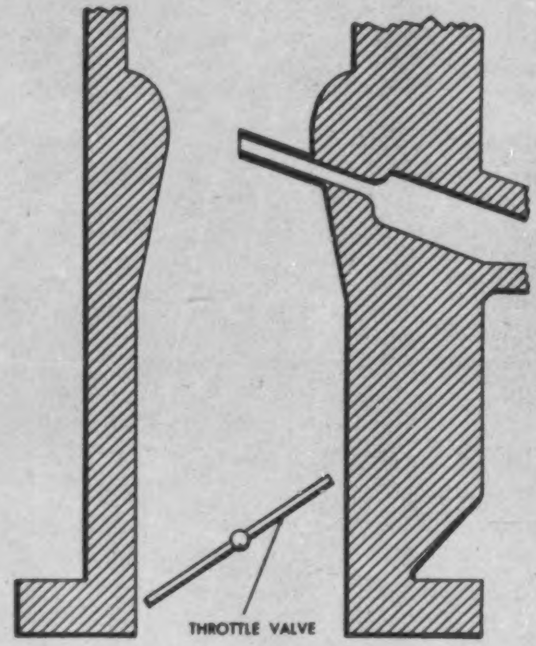

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Figure 7-28.—Simple carburetor with throttle valve.

Float Circuit

The float circuit maintains the fuel level in the carburetor bowl at a constant level during engine operation. (See fig. 7-29). The float circuit automatically permits fuel to flow into the bowl when the fuel level drops below a predetermined level, and shuts off the supply of fuel when the level exceeds the specified height.

Up-and-down movement of the float on the fuel controls the fuel supply by means of a needle valve and seat.

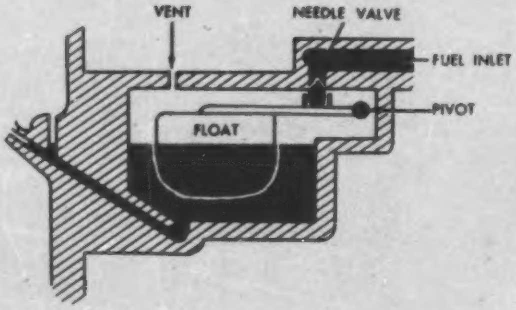

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Figure 7-29.—A typical float circuit.

The float level must be set with accuracy in accordance with the manufacturer's specifications. If the fuel level is too low, insufficient fuel will be supplied to the jets, and engine performance will be sacrificed. On the other hand, if the fuel level is too high, excessive fuel will reach the jets. In fact, fuel may continue to flow from the jets when the engine is stopped. In actual operation, the float and needle valve maintain a position that permits the fuel coming in to just balance the fuel that is flowing to the jets.

Low-Speed Circuit

When the throttle is almost closed, there will be very little air passing through the venturi. Therefore, there will be very little vacuum at the venturi and the fuel nozzle will not discharge any appreciable amount of fuel. Without some additional circuit to assure fuel delivery with a closed throttle, the engine would stop. The circuit that takes care of fuel delivery during closed or nearly closed throttle is called the idle- and low-speed circuit (fig. 7-30). Actually in some respects, this is really two circuits; an idle circuit and a low-speed circuit.

When the throttle is closed, there is a relatively high vacuum in the intake manifold and below the throttle. The idle circuit has a discharge port, or hole, that is just below the throttle valve when it is closed. With a closed throttle, there is a vacuum in the intake manifold and, therefore, at the discharge hole. Atmospheric pressure in the float bowl will force fuel from the float bowl through the idle circuit and out the discharge hole. An adjustable needle valve is arranged to permit more or less fuel to discharge from the hole; this makes it possible to adjust the idling mixture richness by allowing more or less fuel to discharge during idle.

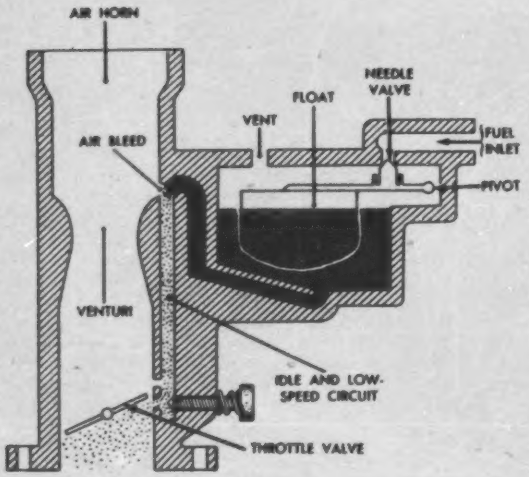

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Figure 7-30.—A simplified idle- and low-speed circuit.

An air bleed is arranged to allow air to bleed into the idle circuit when it is operating. This air mixes with the fuel and partly atomizes it before it discharges from the hole into the air horn. Some such assistance is needed because air movement through the horn is much slower and, therefore, there is less tendency for atomization to take place at the hole during idle. The air bleed also helps to produce fuel flow when pressure differences (between upper and lower portions of the air horn) are low; the mixture flows easier than liquid alone.

When the throttle is opened a little, the airflow is still too restricted for the venturi to discharge fuel. Yet more air is flowing and, consequently, more fuel must discharge. The idle-circuit discharge hole alone cannot supply this additional fuel. To supply the additional fuel needed for this low-speed operation, an additional hole (low-speed discharge hole or port) is included in the idle circuit. This hole is so placed that it is slightly above the edge of the throttle valve when it is closed, but slightly below the edge of the throttle valve when it is opened a small amount. In this latter position, intake manifold vacuum can act on the low-speed hole and therefore supply additional fuel from the bowl through the circuit. The same circuit is used by both the idle- and low-speed holes. The low-speed hole simply permits more fuel to discharge into the throttle-valve body as the throttle is swung away from the fully closed position.

High-Speed Circuit

The high-speed circuit consists essentially of the main nozzle, which is centered in the venturi. The carburetor normally contains a multiple venturi; that is, several venturi, one inside another. When the throttle is opened sufficiently, the air passing through creates a pressure difference which causes a discharge of fuel from the nozzle. Throughout the intermediate and high-speed range, this discharge increases with the volume of air passing through so that a fairly uniform fuel-air mixture ratio is maintained. Assisting in maintaining this fairly constant ratio is an air bleed which is

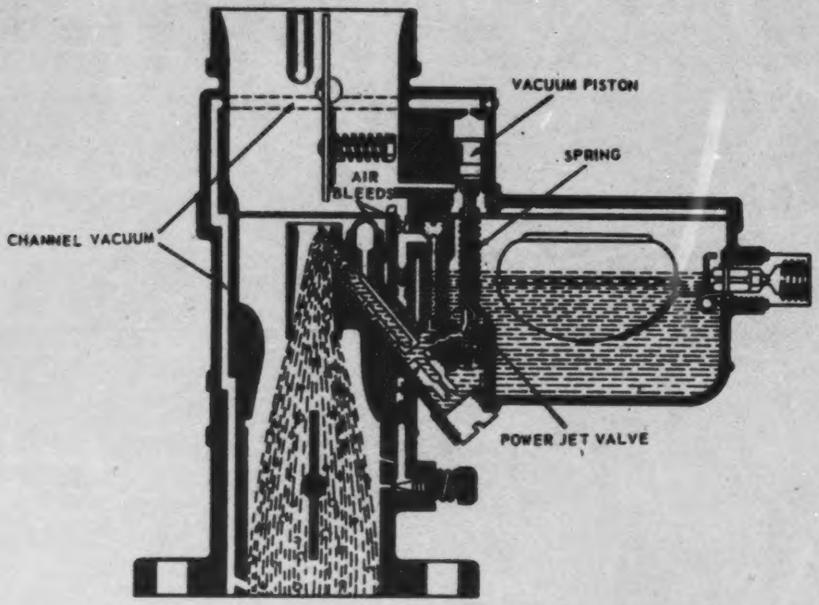

Figure 7-31.—Power jet full load circuit.

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incorporated in the nozzle. With increased airspeed through the venturi, increased air bleeding into the main nozzle takes place, preventing over-richness. Note the air bleeds in figures 7-31 and 7-32.

The high-speed and low-speed circuits overlap. As the throttle is moved from closed to opened position, for example, the idle low-speed and high-speed circuits successively take over the main job of supplying fuel. With a closed throttle, the idle discharge hole alone supplies fuel. As the throttle is opened so its edge moves past the low-speed hole, the low-speed hole begins to discharge fuel to meet the added fuel requirements of the engine as engine speed increases. As the throttle opens still wider, the additional and faster-moving air through the air horn begins to produce fuel discharge from the main nozzle. As the main nozzle takes over, the low-speed discharge hole is closed.

The carburetor is so designed that the fuel-air ratio of the mixture supplied with an open throttle provides economical operation. This ratio is somewhere around 15:1, by weight.

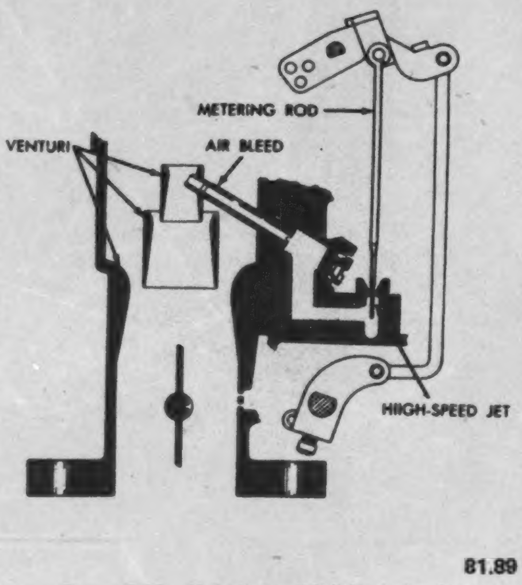

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Figure 7-32.—Metering rod full load circuit.

If the mixture is enriched to around 11:1 or 12:1, the engine will produce greater power, even though it will not run quite as economically. To increase engine power for high-speed or heavy-load operation (as when pulling up a hill), and still maintain reasonable economy, an additional circuit is included in the carburetor which enriches the mixture with a wide-open throttle. This is known as the full-load high-speed circuit and may be one of several types.

POWER JET.—In some carburetors, a power jet provides the additional fuel necessary for maximum power at wide-open throttle. The power jet valve (fig. 7-31) controlled by a vacuum-actuated piston assembly, operates in accordance with the throttle opening. With the throttle closed, a high manifold vacuum is present, and the vacuum-controlled piston assembly is moved by atmospheric pressure in the float chamber to the top of its cylinder against the tension of a spring, closing the valve. When the throttle is opened to a point where additional fuel is required, the manifold vacuum has decreased sufficiently so that the spring on the piston assembly moves the piston down, thereby opening the power jet to feed additional fuel into the high-speed circuit. The jet valve is sometimes referred to as the economizer valve since its operation provides full power operation where needed and more economical operation at other times.

METERING ROD.—Instead of using a power jet, some carburetors accomplish the same result by employing a metering rod which varies the size of the high-speed jet openings. Fuel from the float bowl is metered to the high-speed circuit through the calibrated orifice provided by the high-speed jet and the metering rod within it. From this point, the fuel is conducted to the nozzle extending into the venturi. As the throttle valve is opened, its linkage raises the metering rod in the jet. See Fig. 7-32.

The rod has several steps, or tapers, machined on the lower end, and, as it is raised in the jet, it makes the effective size of the fuel orifice greater, permitting more fuel to flow through the circuit to meet the load demand imposed upon the engine. At the wide-open throttle position, the smallest step of the metering rod is in the circular opening of the jet, permitting the maximum amount of fuel to flow through the circuit to meet the requirements of maximum power. The metering rod position must be synchronized with every throttle valve position so that the proper ratio of air and gasoline is delivered to the engine for all speeds and driving conditions.

VACUUM STEP-UP.—The vacuum step-up (fig. 7-33) operates much like the power jet. It consists of a step-up piston which is fastened to a step-up rod. When high vacuum develops in the intake manifold, as it does under part-throttle operation, atmospheric pressure holds the step-up piston down against its spring pressure so that the step-up rod is held down in the step-up jet, thus, closing off the jet. With wide-open throttle, there will be a low vacuum in the intake manifold and the difference in pressure above and below the piston is small. Consequently, the piston is moved up by its spring pressure and the rod is raised out of the jet. Additional fuel for full-power operation is supplied.

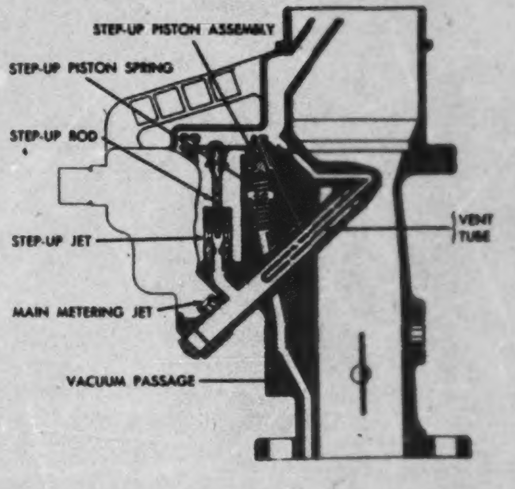

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Figure 7-33.—Vacuum step-up high speed circuit.

Accelerating Pump Circuit

The accelerating pump circuit controls a small amount of fuel that is momentarily discharged into the airstream when the throttle is opened quickly. This extra amount of fuel is necessary to ensure instantaneous response from the engine on acceleration. When the throttle is suddenly opened, air rushes through both the carburetor and the intake manifold. The air is lighter than the liquid fuel and gets into motion quicker, so it reaches the manifold before the fuel charge supplied by the high-speed system. This results in a momentarily lean mixture. To counteract this condition, additional fuel must be supplied; this is accomplished by the accelerating pump circuit.

The accelerating pump circuit consists of a pump cylinder; a plunger mechanically actuated by a lever mounted on the throttle shaft, or vacuum-operated by intake manifold vacuum; an intake check valve located in the bottom of the pump cylinder to control the passage of fuel from the bowl into the pump cylinder; a discharge check valve; and an accelerating jet to meter the amount of fuel used. A typical arrangement with a mechanically-actuated plunger is shown in figure 7-34.

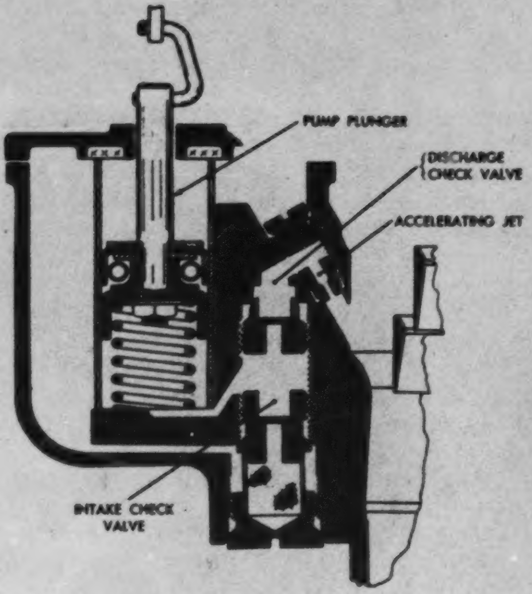

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Figure 7-34.—Carburetor accelerator pump circuit.

When the throttle is opened, the pump plunger moves downward in its cylinder. If the plunger is mechanically operated, the downward movement will be brought about by direct linkage with the throttle. If it is vacuum-actuated, a sudden throttle opening will cause the manifold vacuum to drop, allowing the accelerating-pump spring to force the pump plunger down in the cylinder. In either case, the subsequent action of the accelerating-pump circuit is the same. The downward travel of the plunger forces fuel past the discharge check valve to the accelerating jet, which meters the rate at which it is discharged into the airstream.

Fuel is supplied to the pump cylinder through the intake check valve at the bottom. The level of fuel in the pump cylinder when the plunger is held up to the top of its stroke is approximately equal to the level in the fuel bowl. The intake check valve in the bottom of the cylinder permits a supply of fuel to reach the cylinder but closes on the downstroke of the plunger, preventing the fuel in the cylinder from being pushed back into the bowl. The accelerating pump discharge is needed only momentarily when the throttle is opened suddenly. To prevent the accelerating jet from flowing at constant throttle openings, some models have an air-vent check valve placed between the accelerating jet and pump cylinder above the fuel level.

At steady part-throttle positions, when the pump plunger is inoperative, no pressure exists on the fuel in the pump cylinder. Under this condition, the air-vent check valve will be open and the air will enter the passage connecting the pump cylinder and accelerating jet, preventing fuel from flowing through the jet. The pressure on the fuel, created by the downstroke of the pump plunger, causes the air-vent check valve to close against its seat to prevent the fuel from being discharged back into the bowl through the air-vent passage.

On some carburetors, the area above the plunger is connected to the intake manifold so that the accelerating pump does not work while the engine is not running. Under these conditions, the pressure in the intake manifold is near atmospheric and holds the pump plunger down.

Successful operation of the accelerating pump depends on a delayed action which provides a continual stream of fuel from the pump jet after the throttle has ceased moving. This is to take care of the fuel demands of the engine in the interval that exists between the time the throttle is opened and the time the high-speed nozzle begins to discharge fuel.

Choke Circuit

When the engine is cold, the gasoline vapors tend to condense into large drops on their way to the cylinders. Because all the gasoline supplied to the cylinders will not vaporize, it becomes necessary to supply a richer mixture to have enough vapor to assure combustion. This is accomplished by the choke circuit, which is a choke-valve plate placed in the carburetor throat above the venturi.

When a driver operates the choke, the choke valve tilts in the air horn to reduce the amount of air entering the throat, giving a very rich mixture. Only the volatile parts of the gasoline will vaporize at cold temperatures; therefore, a rich mixture is necessary. It provides enough ignitable vapor to start the engine. However, if the choke valve is in the full-choke position, it is completely closed, shutting off the supply of air. Consequently, there is not enough air entering the throat to allow the gasoline to ignite. The necessary air is admitted in manual chokes by either one of two semiautomatic features.

In one design, the choke valve incorporates a spring-loaded poppet valve (fig. 7-35). The poppet is held in the closed position by a weak spring. As soon as the engine turns over, there is sufficient pressure differential to open the valve, allowing a small amount of air to flow.

In the other design, the valve is offcenter (fig. 7-36) and operated through a coiled spring on the end of the choke shaft. In the full-choke position, the spring holds the choke valve in the closed position. As soon as the engine turns over, an increased pressure differential overcomes the spring tension and opens the choke valve part way, admitting enough air to prevent overchoking or flooding the engine. As the engine warms up, the choke valve is

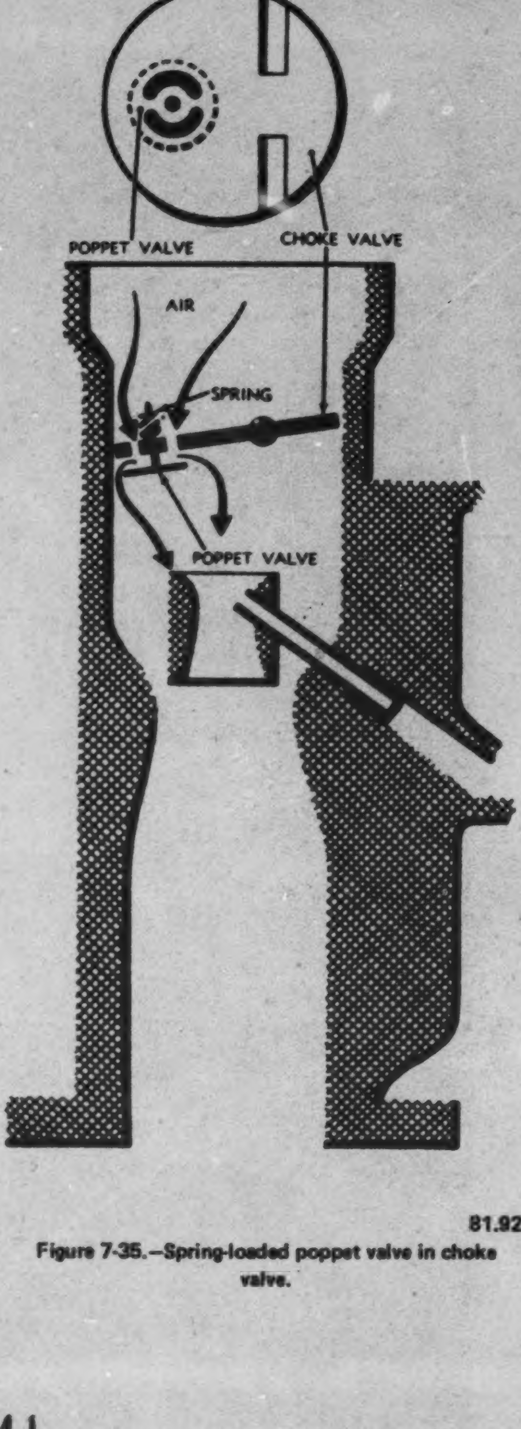

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Figure 7-35.—Spring-loaded poppet valve in choke valve.

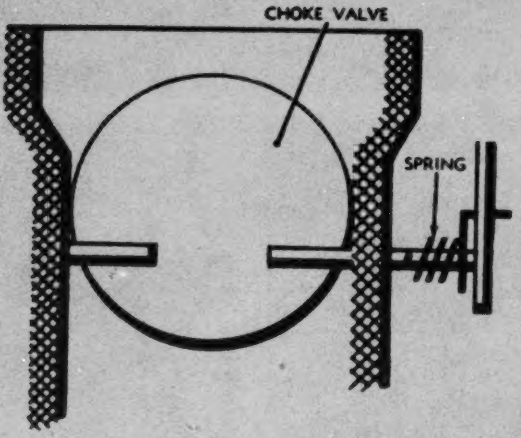
CHOKE VALVE
SPRING

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Figure 7-36.—Offcenter choke valve.

gradually advanced to the wide-open position by the operator to supply the leaner mixture required for a hot engine.

Automatic Choke

The automatic choke (figs. 7-37 and 7-38) replaces the conventional manual choke. It not only controls the fuel-air ratio for quick starting at any temperature, but also provides for the proper amount of choking to enrich the fuel-air mixture for all conditions of engine operation during the warmup period. The automatic choke is built into the carburetor. It consists of a thermostatic (bimetal) spring and a vacuum piston which opposes the action of the spring. The spring is connected to the choke valve in such a manner as to close the valve when the spring is cold. The vacuum piston tends to open the choke valve when the engine manifold vacuum is high. The choke valve is mounted

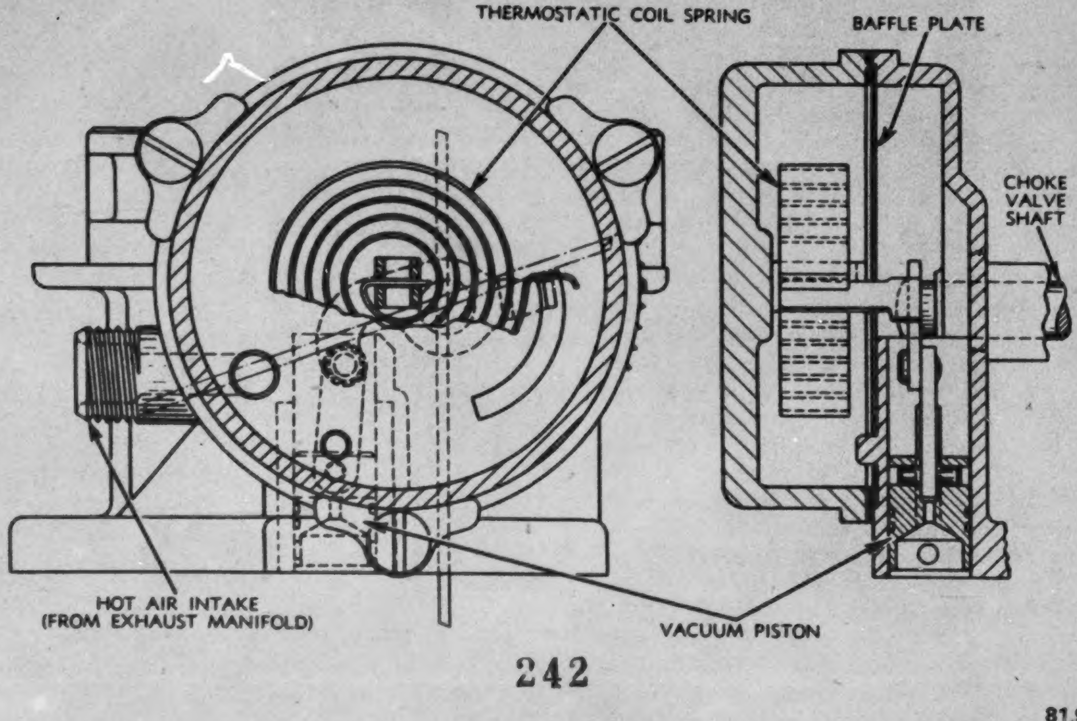
THERMOSTATIC COIL SPRING
BAFFLE PLATE
CHOKE VALVE SHAFT
HOT AIR INTAKE (FROM EXHAUST MANIFOLD)
VACUUM PISTON

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Figure 7-37.—Automatic choke, cutaway view.

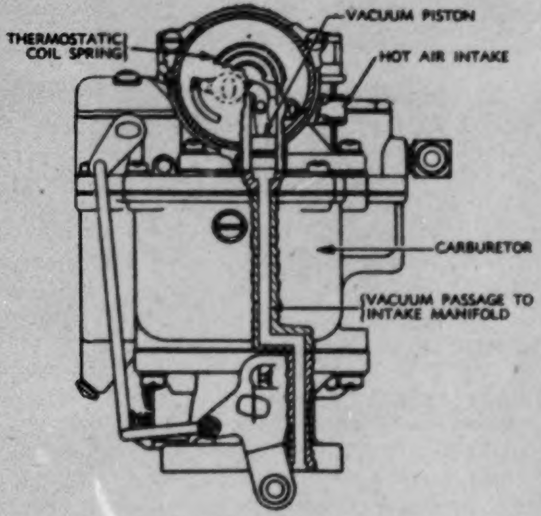

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Figure 7-38.–Location of automatic choke on carburetor.

offcenter on the choke shaft so that any increase in air velocity through the air horn will tend to open the valve.

The operation of the automatic choke is dependent on three factors: heat, intake manifold vacuum, and the velocity of air passing through the air horn. When the engine is cold, the thermostatic spring holds the choke valve closed. When the engine is started, the low pressure (high vacuum) below the throttle valve permits atmospheric pressure to move the piston down and partially open the valve against the tension of the thermostatic spring. Under varying load conditions during warmup, the position of the choke valve will be changed by the operation of the vacuum piston working against the thermostatic spring, and the air velocity in the air horn. Hot air from the exhaust manifold is directed to the thermostatic spring so that the spring loses its tension as the engine is heated. This permits the choke to open gradually and, after it reaches the full open position, it is held open by the action of the intake manifold on the piston. When the engine is stopped, the thermostatic spring cools and closes the choke valve. The choke valve is fully closed at a temperature of approximately 70° F.

Carburetor Maintenance and Repair

Listed in the following paragraphs, are some of the engine troubles that usually (but not always) can be traced to some fault in the carburetor system:

1. EXCESSIVE FUEL CONSUMPTION can result from a high float level, a leaky float, a sticking metering rod or full-power piston, sticking accelerator pump, and too rich an idling mixture.
2. A SLUGGISH ENGINE can be the result of a poorly operating accelerator pump, sticking high-speed piston, low float level, dirty or gummy fuel passages, or a clogged air cleaner.
3. POOR IDLING, often characterized by a stalling of the engine, usually is due to injection of an excessive amount of fuel, a defective choke, or an incorrectly adjusted idle speed screw.
4. FAILURE OF THE ENGINE TO START may be caused by an incorrectly adjusted choke, clogged fuel lines, or air leak into the intake manifold.
5. HARD STARTING OF A WARM ENGINE could be due to a defective or improperly adjusted throttle link.
6. SLOW ENGINE WARMUP may indicate a defective choke.
7. A SMOKY, BLACK EXHAUST indicates a very rich air-fuel mixture.
8. STALLING OF THE ENGINE AS IT WARMS could be caused by a defective choke or closed choke valve.
9. A BACKFIRING ENGINE may be due to an incorrect, often lean, air-fuel mixture reaching the engine. In turn, this condition could be caused by clogged fuel lines or a fluctuating fuel level.

The more stubborn troubles in a carburetor can sometimes be eliminated only with its disassembly and overhauling. The procedures vary according to the manufacturer's specifications, which you should follow closely. If you do not have them, follow these general instructions:

To remove the carburetor, first take off the air cleaner. Now disconnect the throttle and choke linkages and the fuel lines; use two wrenches, if necessary, to avoid damage to the lines or the couplings. When lifting off the carburetor after removing the attaching nuts and bolts, be careful not to jar it, because any accumulations of dirt in the float bowl might be stirred up and foul the fuel circuits.

Clean all openings and passages with an approved solvent. Replace rather than repair all worn, scored, or burred parts.

If possible, clean the carburetor either out of doors or in a well-ventilated section of the shop. If you use low-pressure air to blow out encrusted matter, wear goggles to protect your eyes from foreign particles.

After the carburetor has been cleaned and overhauled, put on a new gasket and reattach the carburetor to the intake manifold with the nuts and bolts. Reconnect the fuel line, again using two wrenches, if necessary, to avoid damage to the lines or couplings. After making the idle speed and idle mixture adjustments, reinstall the air cleaner.

Your shop may have a special carburetor overhaul kit which contains the necessary tools for doing a cleaning and overhauling job.

Gasoline will turn to vapor when sufficient heat is applied to it. When this takes place in the fuel lines, fuel pump, or carburetor of automotive equipment, the fuel system is vapor locked. Under vapor-lock conditions, loss of power and missing can occur and the engine may even stop. Carburetors are usually provided with vents that overcome or reduce the tendency toward vapor lock. Fuel pumps and lines are placed away from the exhaust system heat, which also helps to reduce or prevent vapor lock. Should the engine stop because of vapor lock, the discrepancy will usually correct itself if sufficient time is allowed to cool the engine. In extreme cases the fuel lines may need to be bled. This requires disconnecting the fuel line at the fuel pump or carburetor and permitting the fuel to flow long enough to bleed the vapor from the line.

Air Cleaner

The air cleaner is placed at the air entrance of the carburetor to remove dust and other foreign matter from the air before it enters the carburetor. A great deal of air, as much as 100,000 cubic feet for every 10,000 car miles, is introduced into the engine. Without an air cleaner, dust and grit would enter the engine with the air and would cause excessive wear and operating troubles.

Two types of air cleaner are used: a wet-type and a dry-type.

The wet-type air cleaner (fig. 7-39) is an oil-bath cleaner, consisting of a main body and a cover. Within this unit are a reservoir of oil and a filter element made of copper gauze or fine mesh threads. Air entering the cleaner passes through small ports at the top of the body, then through the gauze material that traps virtually all foreign particles. Next, the air flows past the oil-filled reservoir, picking up particles of oil and carrying them through the filter. The air finally hits the cover plate and is deflected down through a passage to the carburetor.

The gauze or threads in the filter also act as a flame arrester in case of severe flashback or backfire. Many air cleaners are equipped also with a silencing unit called the sound neutralizing chamber. It consists of air-intake passages designed to muffle air noises, and a felt pad that acts as a gasket and absorbs engine intake noises.

The usual dry-type air cleaner (fig. 7-40) uses a copper gauze cleaner element and a cover plate with a felt pad, which remove dust and dirt from the air as it passes toward the carburetor. This cleaner has the disadvantage of easily becoming clogged. Clogging will result in reduced engine power.

Some of the late model vehicles are equipped with paper filters which require no servicing, but should be replaced at 15,000-mile intervals or more often in dusty areas.

A clogged air cleaner will cause mixtures that are too rich and result in excessive fuel consumption. Foreign matter passed into the engine because of such a poor cleaner will also

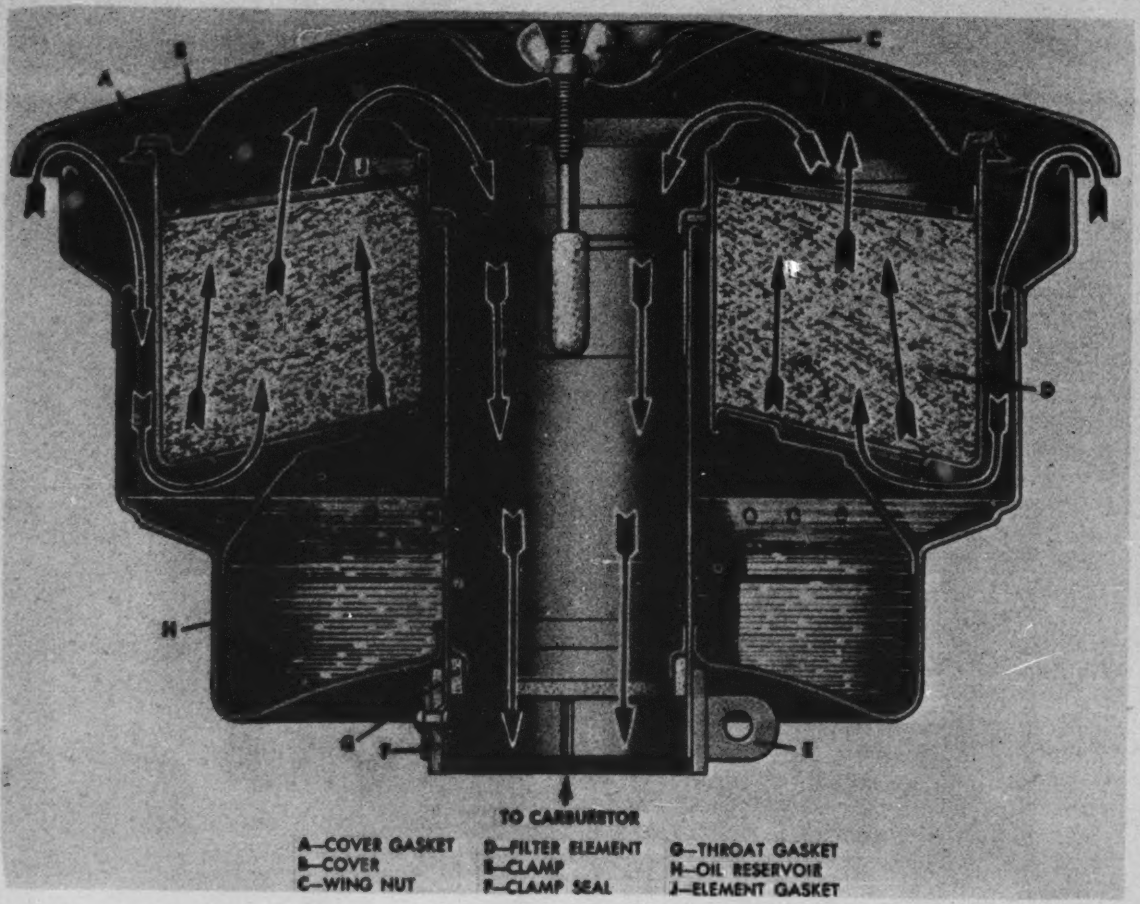
A
B
C
D
E
F
G
H
TO CARBURETOR
A–COVER GASKET
B–COVER
C–WING NUT
D–FILTER ELEMENT
E–CLAMP
F–CLAMP SEAL
G–THROAT GASKET
H–OIL RESERVOIR
J–ELEMENT GASKET

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Figure 7-39.–Wet-type air cleaner.

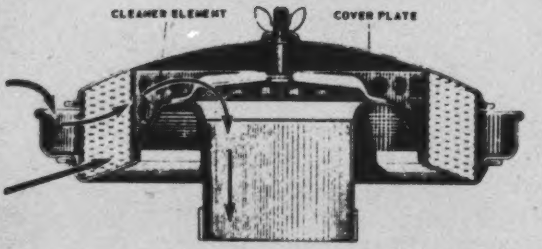
CLEANER ELEMENT
COVER PLATE

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Figure 7-40.–Dry-type air cleaner.

cause excessive engine wear and operating troubles.

At each chassis lubrication remove the air cleaner and wash its filter element in nonflammable cleaning solvent. Never wash it in gasoline, for gasoline could be ignited by static electricity, or even by the friction of rubbing surfaces. Wash the cleaner case as well as the filter element. In wet-type cleaners, drain the old oil and add new oil. Be sure that the weight of the new oil conforms to the manufacturer's specifications, and that you add it to the level indicated on the filter body.

AIR INDUCTION AND EXHAUST SYSTEMS

In chapter 6 you learned that intake and exhaust are two of the four basic engine strokes. The intake stroke admits an air-fuel mixture into the cylinder, and the exhaust stroke expels the used gases from the engine cylinder. In this section, you will be concerned with the intake manifold and the exhaust manifold, the passageways through which the mixtures are admitted and the gases expelled.

The intake manifold is usually a cast iron passage through which the air-fuel mixture passes to each cylinder. The intake manifold should be as short and straight as possible to reduce chances of condensation. The manifold is mounted on the side of the cylinder block in L-head engines, on the side of the cylinder head in I-head engines, and between the two cylinder banks in V-8 engines. The intake manifold is fastened by capscrews or held in place by studs extending from the cylinder block. It is secured by a nut and special washer on each stud. The mounting flange for the carburetor is centrally located on the intake manifold so that a uniform mixture can reach the individual cylinders. Connections between the engine block and the manifold, and between the carburetor and the manifold, must be airtight. They are usually sealed by thick gaskets which allow for any slight irregularity in the joining metal surfaces. Leaks and cracks permit air to enter the engine without passing through the carburetor, resulting in a lean and possibly dirty mixture (air containing dust and foreign particles).

The exhaust manifold is usually a cast iron passage through which the used gases are carried away from the engine cylinders. It is attached to the side of the cylinder block on L-head engines and to the side of the cylinder head on I-head engines. On V-8 engines there are two exhaust manifolds, one for each bank of cylinders, which are usually connected by a crossover pipe and exhaust through a common muffler and tailpipe. Some vehicles with dual exhausts, have two mufflers and two tailpipes, which increase the efficiency of the engine by reducing back pressure.

The gasket between the exhaust manifold and the cylinder block or cylinder head must withstand the intense heat of the exhaust gases. Although gaskets are made of metal-covered asbestos, they can burn, and they will have to be replaced if the connections become loose. Exhaust gas leaks can be detected by smoke discolorations at the connections. If the leak is bad enough, it can be felt and heard when the engine is running.

A device called a manifold heat control valve is often built into the exhaust manifold to promote better vaporization of the fuel. During engine warmup, particularly in cold weather, evaporation of the gasoline in the air-fuel mixture entering the engine is poor, since gasoline evaporates more slowly when it is cold. To assist in the vaporization of the fuel, the heat control valve deflects the exhaust gases toward the intake manifold (shown in fig. 7-41), when the engine temperature is low. As the hot exhaust gases pass around the intake manifold, they heat the manifold and the incoming air-fuel mixture also is heated. When the engine is warmed up enough to ensure adequate vaporization of the fuel, the valve turns to the right as shown in figure 7-41. Now the used gases are deflected downward into the exhaust pipe and no longer circulate around the intake manifold. The space around the intake manifold which is heated by exhaust gases is sometimes called the "hot spot."

Before reaching the tailpipe, the used gases pass down the exhaust pipe through the muffler (fig. 7-42). Together with the exhaust pipe and tailpipe, it comprises the exhaust system of the engine.

The muffler quiets the noise of the exhaust by reducing the pressure of the used gases. These gases expand and cool in the separate chambers of the muffler. Flames and sparks leaving the exhaust manifold with the gases are "trapped" by the muffler, which also acts as a flame arrester.

The muffler is connected between the exhaust pipe and the tailpipe by slip joints and clamps and is supported from the frame of the vehicle by metal straps. When you install a muffler, be sure that the small drain hole in the

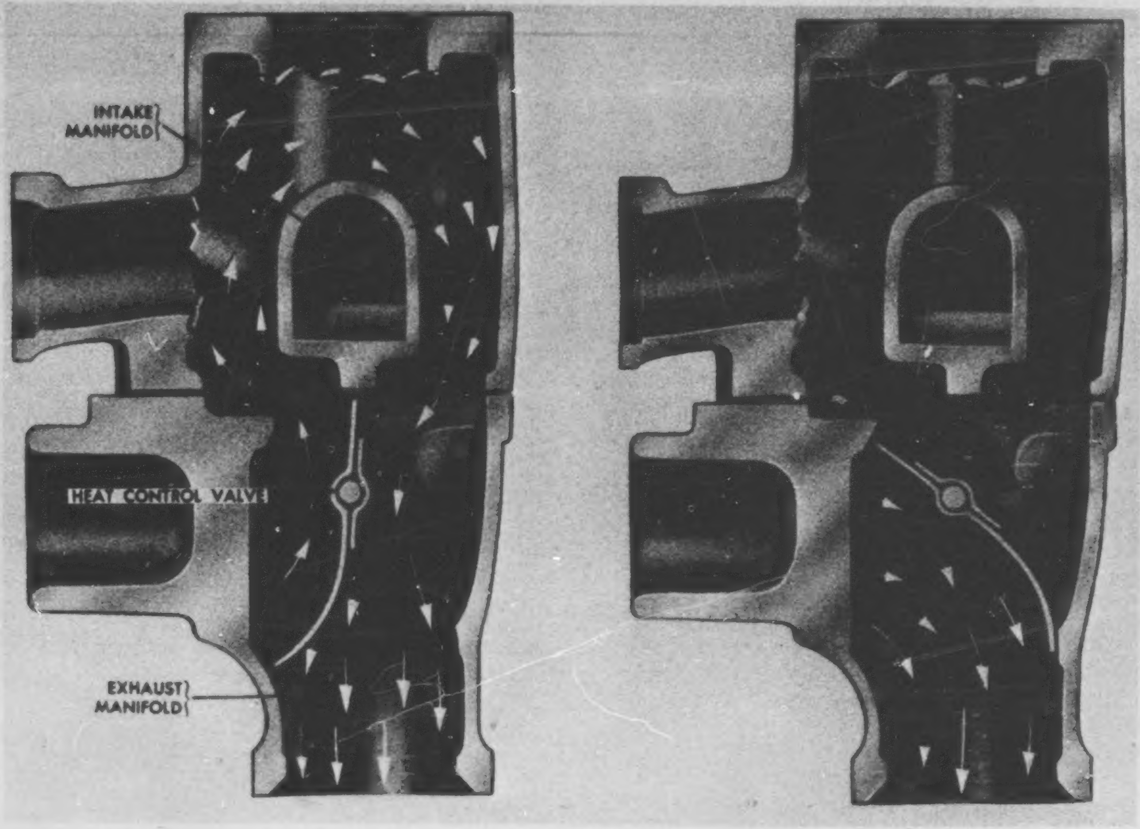

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Figure 7-41.–Flow of exhaust gases around intake manifold.

case is at the bottom and that the clamp fasteners are tight.

Rust on the outside of the muffler is caused by snow, rain, and humidity. Rust on the inside results from burning fuel. You have learned that the products of combustion contain water in suspension. This water, trapped in the muffler, will gradually rust it. With every gallon of gasoline that is burned, approximately 6.9 pounds of water are formed and pass through the muffler. Much of this moisture will remain in the muffler if the vehicle is driven only short distances, but most of it will be expelled if the vehicle is driven speedily for a long distance. In time, the rust, together with the pressure of the exhaust gases, will force holes in the muffler. Through these holes the poisonous fumes of carbon monoxide will seep into the vehicle and can affect the occupants, sometimes fatally.

Mufflers must be replaced immediately if they are known to be defective. They should also be replaced if suspected of being clogged with carbon particles or other foreign matter. Inability of the engine to develop maximum power, difficult starting, and operation of the engine at higher than normal temperatures may indicate clogging of either the muffler or another part of the exhaust system.

The muffler tailpipe or outlet pipe, which extends to the rear of the vehicle (or over the cab on some equipment) should be kept open so that the exhaust gases can escape easily. A

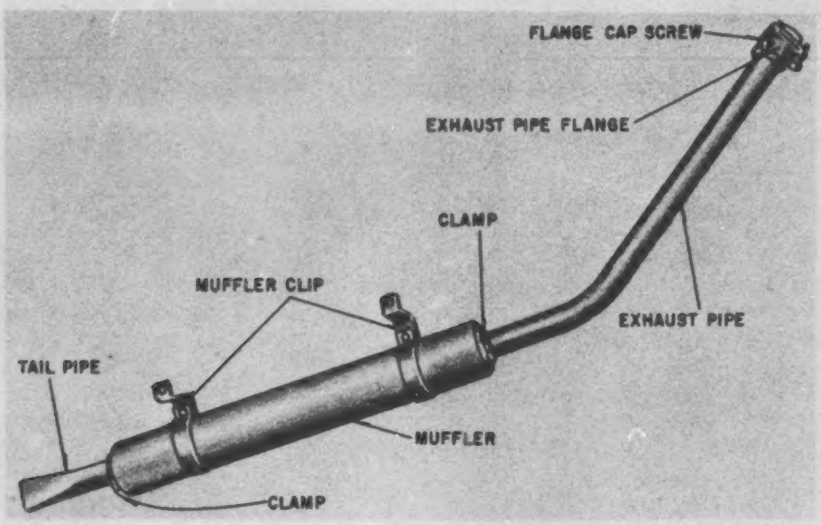

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Figure 7-42.—Exhaust pipe, muffler, and tailpipe.

pinched or partly closed tailpipe can affect engine operation to the extent that the engine may stop. Unless the used gases are removed from the cylinders, a fresh mixture cannot enter.

PERFORMANCE

The performance of the engine is determined by the efficiency of the engine or its ability to perform the desired function. Substandard performance or malfunctions will result in poor engine performance and higher operating costs.

Satisfactory engine performance depends on the proper ignition, compression, and carburetion. If the ignition system has burned points and fouled or worn spark plugs, the engine will not develop full power. The ignition spark must occur at the right time and with sufficient intensity to ignite the compressed air-fuel mixture. Proper ignition requires the satisfactory operation of the coil, distributor, spark plugs, and spark advance system.

There must be no leakage of the compression in the cylinders for satisfactory and economic operation of the engine. This means that the intake and exhaust valves, the gaskets, and the piston rings must perform their functions properly and allow no leakage. Rough operation of the engine results from uneven power strokes caused by leakage in one or more cylinders and causes a reduction in performance and economy.

The carburetor must deliver the correct mixture of air and fuel for all conditions of engine operation. An improperly operating carburetor can cause the mixture to be too rich or too lean. A rich mixture causes spark plug fouling and loss of power and is uneconomical. Overheating, preignition, loss of power, and engine damage can be caused by a lean mixture. The carburetor must be supported by a properly functioning pump, lines, tank, air cleaner, intake manifold, and intake valve to deliver the correct mixture to the combustion chamber.

Other factors affecting engine performance are the age of the engine or the time since overhaul, quality of the fuel used, and the ability of the operator. An engine may perform as efficiently as possible, but losses of power still result from worn piston rings and valves, even though the parts are not worn enough to warrant replacement. Substandard or contaminated fuel will cause the engine to perform below maximum power. An engine that is able to perform satisfactorily can give substandard performance when operated by an incompetent operator.

The initial evaluation of the engine performance is afforded by observing the engine instruments on the instrument panel. These will usually include coolant temperature gage, oil pressure gage, tachometer, ammeter, and fuel gage. If the temperature of the coolant is too high, it can indicate a malfunction of the cooling system, air-fuel mixture too lean, and/or ignition timing too early. Low oil pressure usually indicates that oil should be added to the engine. Using the incorrect viscosity of oil in an engine can cause the oil pressure gage to indicate outside the normal operating range. Viscosity of oil will be explained in chapter 11 of this training manual.

The tachometer fluctuation indicates a rough running engine. The ammeter indicates the amount of current flowing to and from the battery. If the ammeter indicates discharge when the engine is operating above idling speed, this usually means the generator or voltage regulator has malfunctioned. The fuel gage can tell you that the fuel supply is exhausted. The instrument panel may have a hydraulic-pressure gage, an hourmeter, a torque-converter temperature gage, an air-pressure gage, and/or cylinder temperature gage. The uses of these instruments are explained in the operation and maintenance publications on the vehicle or engine on which they appear.

The quickest, easiest, and most reliable method of determining the repair requirements of a gasoline engine is by scientific testing. An accurate picture of the engine's condition can be determined by the comparison of the information obtained from a series of tests with known specifications and standards. An engine analyzer is the best instrument for obtaining this information.

An engine analyzer can indicate the true condition of an engine and permit the mechanic to recommend the action necessary to restore the engine to full operating efficiency. The manufacturer's manual for the engine analyzer should be studied carefully, and the use of the analyzer should be supervised closely until proficiency is reached.

A widely used engine analyzer is manufactured by the Sun Electric Corporation. This analyzer includes an ignition tester, a volt-ohm-condenser tester, a breaker point tester, a coil tester, a tachometer, a vacuum-pressure gage, a weak cylinder tester, a cylinder leakage tester, a combustion efficiency tester, a timing light, a timing advance tester, an exhaust gas analyzer, and a fuel-pump tester. Most of these testers and instruments are covered individually in chapter 2 of this training manual. All tests can be conducted, and all indications of engine performance can be read, when the engine is hooked up to the engine analyzer. The analyzer also permits the mechanic to perform critical adjustments that are so essential to an engine's efficient and dependable performance.

Another widely used engine analyzer is manufactured by the Simpson Company. This analyzer combines many of the automotive testers discussed previously and consists of the following testers:

1. Tachometer–the tachometer is designed for use on 6-, 12-, 24-, and 32-volt electrical systems of both the battery and magneto types. The rpm ranges are represented on two scales: a 0-1,000 rpm scale and a 0-8,000 rpm scale.

2. Dwell meter–the dwell meter can be used on 6-, 12-, 24-, and 32-volt systems. It will indicate the dwell interval for 4-, 6-, and 8-cylinder engines.

3. Vacuum gage–the vacuum gage will read manifold vacuum in both inches and millimeters of mercury.

4. Fuel flow and pressure gage–the fuel flow and pressure gage will read pressure in psi and fuel flow in pints per minute.

5. Cylinder condition analyzer–the cylinder analyzer will accurately pinpoint the location and the extent of compression leaks before engine disassembly.

6. Timing advance indicator–the timing indicator will perform speedy initial timing checks and fast accurate measurement of distributor advance mechanism operation while the engine is running. A tachometer is provided with this test indicator.

7. Coil tester–the coil tester is capable of testing the coil's primary and secondary windings for opens, continuity, grounds, stress voltages, and insulation leakage.

8. Condenser tester–the condenser tester is capable of testing the three basic functions required–series resistance, leakage, and capacitance.

9. Ammeter–the ammeter is capable of reading currents up to 300 amperes. As with other components, it works on voltages of 6, 12, 24, and 32.

10. Voltmeter–the voltmeter is capable of testing voltages of 6-, 12-, 24-, and 32-volt systems.

11. Ohmmeter–the ohmmeter can provide continuity readings and accurate resistance readings to 100,000 ohms.

12. Battery-starter tester–this tester will test starter cranking voltage, battery volt leakage, battery capacity and condition, starter amperage draw, and circuit resistance of switches, cables, and connections.

13. Generator, voltage, and current regulator tester–this tester will test the voltage, amperage, and resistance, as applicable, in generators, relays, and wiring in all 6-, 12-, 24-, and 32-volt ac and dc systems. Specific testing capabilities include current draw of ac and dc generator fields, ac and dc generator output, regulator opening and closing voltages, and voltage and current regulator settings.

14. Ignition tester–this unit will measure the resistance and insulation (leakage) of both primary and secondary ignition circuits.

15. Remote starter-ignition switch–this switch will allow engine starter and ignition control from underhood positions.

16. Accessories–the accessories include a complete kit of all required connectors, adapters, and charts necessary for checking both waterproof and nonwaterproof automotive systems.

17. Stand–the stand is a complete enclosed storage cabinet capable of storing all the analyzer components.

The analyzer components may be removed from the analyzer stand and used as individual testers. Each of the large components is provided with its own carrying case.

MALFUNCTIONS

Some of the malfunctions of the gasoline engine have just been discussed under the heading of performance. Others are covered in the following discussion.

When the starting system fails to rotate the engine fast enough to start, any one or a combination of three typical malfunctions may be present. The most common is that the battery is weak or dead. Testing the battery or replacing it with a fully-charged battery of the proper capacity will eliminate the battery as a cause. The second cause may be poor connections between battery and starter. Inspect the cables for breaks or corroded connections. If necessary, remove the cables, test them for current-carrying capacity, clean the terminals, and replace. The third cause is that the starting motor may be malfunctioning. If the starting motor can be heard rotating, the engaging part is not operating properly or the teeth of the starting motor drive or of the flywheel are worn or missing. After the starting motor is removed it can be bench tested to determine the cause of malfunction.

If the starting system is operating properly and the engine still does not start, further investigation is necessary. This can be divided into ignition testing, fuel testing, and compression testing.

A simple ignition test is to remove a spark plug lead and hold it away from the spark plug terminal with an insulated holder while the engine is turned over by the starting motor. Absence of a spark indicates malfunction of the electrical ignition system, and the ASE should be notified. When the spark appears to be strong, the spark plugs should be checked to determine that they are delivering the spark to the combustion chamber. Testing spark plugs has been discussed previously in this chapter.

If the ignition system is found to be operating properly, fuel testing and compression testing are indicated. Fuel-pump testing and carburetor malfunctions have already been discussed in this chapter. Compression testing is discussed in the following paragraph.

Compression of each cylinder should be tested with a compression tester as covered in chapter 2 of this training manual. Any variation of the pressure between cylinders should not be over 15 psi. If one cylinder is low, put a small amount of heavy oil in the low piston and turn the engine over several times to work the oil around the piston. Again use the tester. If the pressure measures higher than before, the compression loss is past the piston and rings, indicating worn rings. If the pressure does not increase, the valves are not seating properly. A loss of compression in two adjacent cylinders indicates a defective cylinder head gasket.

Using too much oil is a common malfunction of an engine. Oil is lost from an engine by leaking, by being burned in the combustion chamber, or by being vaporized in the crankcase and passing out the crankcase ventilating system. Inspect the engine for oil around the seals of the oil pan, valve-cover plate, and timing-gear housing, and around oil lines and oil filter connections. Replace the seals if found leaking.

Oil being burned in the combustion chamber is detected by idling the engine a short time, accelerating the engine, and observing the exhaust pipe. A blue-gray smoke emerging from the exhaust indicates oil being burned in the engine. Oil can get in the combustion chamber past piston rings, valve guides, and vacuum booster pump and through the positive-type crankcase ventilating system. Consult the engine manufacturer's instructions for the remedy to these malfunctions.

A clogged draft-type crankcase ventilating system can cause pressure to be built up in the crankcase and contribute to oil leaks. Inspection can detect whether the inlet breather cap or the vent in the outlet tube is clogged. Cleaning will remedy the defect.

The thermostat in the engine cooling system controls the temperature of the coolant to regulate the engine operating temperature and to provide for short warmup period. When the engine overheats, does not come up to operating temperature, or takes too long to warm up, inspect and test the thermostat. Insufficient coolant, rust, and scale in the system, fan belt slipping, radiator or hoses clogged, and defective water pump are some of the causes of the engine overheating that are the fault of the cooling system. Inspection of the coolant, fan belt, radiator hoses, and water pump should detect the cause. Replace parts where defective.

The loss of power in an engine and a rough-running engine may be attributed to a variety of causes. Probably the best method of determining the cause will be to perform a complete tuneup. The tuneup may determine that the air cleaner is clogged, the carburetor is delivering improper amounts of fuel, or the automatic choke is not operating properly. The fault may be in the ignition system or caused by the valves, exhaust system, or the cooling system.

TUNEUP

To tune an engine means to make the adjustments necessary to bring the engine to first class operating conditions. The aviation support equipment Maintenance Requirement Cards list engine tuneup as part of the periodic work to be performed. This tuneup will often correct malfunctions before they become serious enough to reduce the performance of the engine. The engine manufacturer's specifications should be used for the tuneup.

First, clean the engine to improve visual inspection and eliminate the dirt, dust, and oil deposits from complicating the tuneup procedures. When a dynamometer and an engine analyzer are available they greatly improve the ease and quality of the tuneup. The purpose and use of the dynamometer is described in chapter 2 of this training manual. The engine analyzer was described previously in this chapter. When used together to tune the engine, the fine adjustments necessary to place the engine in the best possible operating condition become a matter of scientific accuracy.

The ASE and the ASM perform the electrical system part of the tuneup. In addition to the corrections indicated to be made on the engine by the analyzer, other inspections and adjustments should be made. The radiator, water hoses, and block should be inspected for leaks. The coolant should be checked for evidence of contaminants. The tightness of the fan belt should be compared to the manufacturer's specifications and adjusted if required.

The oil level must be satisfactory or the oil and oil filter changed if it is time to do so. The intake and exhaust manifolds should be checked for tightness and leaks. The muffler and exhaust pipe should be clear of obstructions and leaks.

Fuel lines, fuel pump, and carburetor should be checked for leaks. The output of the fuel pump and the adjustments of the carburetor can be checked by the engine analyzer. In addition, the air cleaner and fuel filter should be cleaned or replaced as necessary.

If the engine mountings are loose or broken, the engine may vibrate violently when accelerated. A knock may occur if the rubber mountings are drawn down too tight or are worn enough to allow the metal parts to contact each other. Replace if defective.

Safety during tuneups includes the general safety regulations as covered in chapter 3 of this training manual. In addition the safety precautions covered in chapter 2 for the use of tools apply. When the tuneup is done in the aviation support equipment shop, the shop safety regulations serve as a further guide for safe practices.

INSPECTIONS

In addition to the inspections already discussed in connection with detecting malfunctions and tuneups, the Navy requires periodic inspections of engines on the aviation support equipment. The Maintenance Requirement Cards list the inspections and the time they will be performed. The safety requirements are the same as listed for tuneups. To perform the inspections, draw the cards for the inspection to be conducted. The inspections are usually divided into two categories: preoperational and periodic. The preoperational inspections are to be conducted each day before the engine is used and include those to be conducted in less time than 200 hours or 60 days. Periodic inspections are those to be conducted in 60 days or 200 hours and those going beyond this time. Bear in mind that the inspection for an engine is usually only part of the inspection for the equipment on which the engine is used.

The cards provide the minimum requirements necessary to maintain the equipment. Inspection to a greater depth and at an increased frequency may be required by local conditions. The periodic inspections are to be conducted at the expiration of a stated calendar period, number of miles, or number of hours, whichever occurs first. The period, miles, or hours are the maximum authorized. Discrepancies discovered during inspections must be corrected before the equipment is used.

CHAPTER 8

DIESEL ENGINES

The gasoline engine requires a spark to ignite the air-fuel mixture because the compression temperature of the engine is too low to ignite the gasoline and air mixture. In comparison, the compression temperature of the diesel engine is high enough to ignite the finely atomized diesel fuel that is injected into the combustion chamber. The spark of the gasoline engine is necessary because of the low compression ratios–from a possible 6:1 to a possible 11:1 ratio, the compression pressure is from 110 to 180 psi, and the compression temperature is from 220° to 300° F. This compares with compression ratios of 12:1 to 19:1, compression pressure of 400 to 600 psi, and compression temperatures ranging 850° F and higher for diesel engines.

PRINCIPLES OF OPERATION

In principles of operation, the main differences between the gasoline and the diesel engine are the methods of getting the fuel into the cylinders, and in igniting the air-fuel mixtures. In the gasoline engine the air and gasoline are mixed together at the carburetor. (The fuel is metered by the amount of air passing through the carburetor). The mixture then passes through the intake manifold where it starts to vaporize. Then the mixture enters the cylinder through the intake valve where it is completely vaporized by the heat of compression as the piston moves upward on the compression stroke. When the piston approaches top dead center, the mixture is ignited by a spark from the spark plug.

The diesel engine does not use spark plugs nor a carburetor. On the intake stroke, only fresh air is drawn into the cylinders through the intake valve and manifold. On the compression stroke, the air is compressed to a pressure between 400 and 600 psi, and temperature in the cylinder rises to above 850°F. At the proper time, the diesel fuel is injected into the cylinder by a fuel injection system (the fuel is metered by mechanical means), which usually consists of a pump, fuel lines, and injector nozzle. When the fuel oil enters the cylinder it vaporizes and ignites spontaneously.

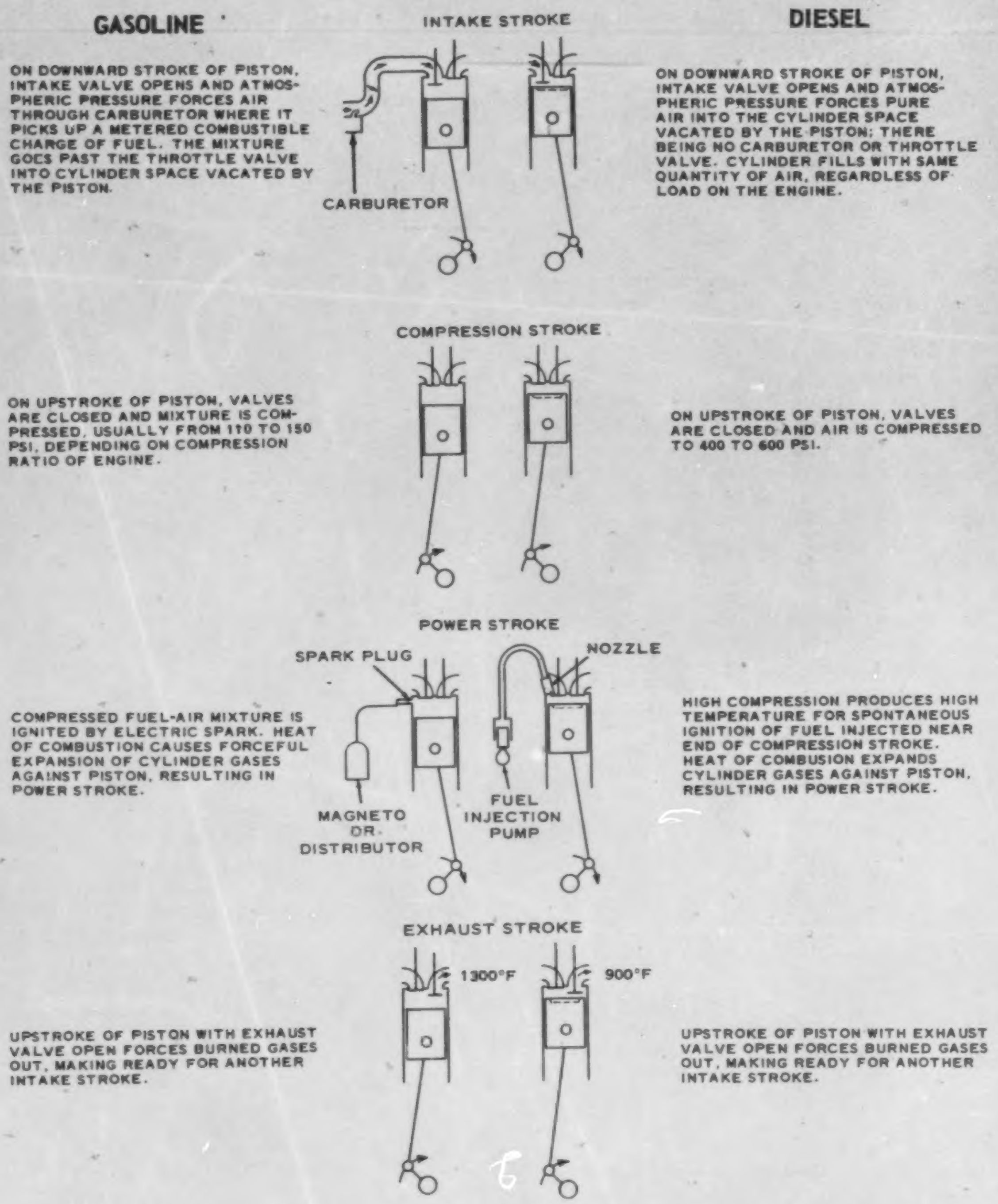
Mechanically, the diesel engine is similar to the gasoline engine. The intake, compression, power, and exhaust strokes occur in the same order as shown in figure 8-1. The arrangement of the pistons, connecting rods, crankshaft, and engine valves is about the same.

ADVANTAGES AND DISADVANTAGES OF THE DIESEL

The main advantages of diesel engines as compared with gasoline engines are high power per pound of fuel (particularly with present day high speed engines), high reliability in operation, low fuel consumption per horsepower per hour, and reduced fire hazard.

The disadvantages of the diesel engine are the high cost of manufacture, the heavier construction necessary to withstand the high compression pressures, and difficulty in starting because of high compression pressure.

At present there are relatively few diesel-engine-powered passenger automobiles, but the use of the diesel engine for small load-and passenger-carrying vehicles is becoming



GASOLINE

DIESEL

INTAKE STROKE

ON DOWNWARD STROKE OF PISTON, INTAKE VALVE OPENS AND ATMOSPHERIC PRESSURE FORCES AIR THROUGH CARBURETOR WHERE IT PICKS UP A METERED COMBUSTIBLE CHARGE OF FUEL. THE MIXTURE GOES PAST THE THROTTLE VALVE INTO CYLINDER SPACE VACATED BY THE PISTON.

ON DOWNWARD STROKE OF PISTON, INTAKE VALVE OPENS AND ATMOSPHERIC PRESSURE FORCES PURE AIR INTO THE CYLINDER SPACE VACATED BY THE PISTON; THERE BEING NO CARBURETOR OR THROTTLE VALVE. CYLINDER FILLS WITH SAME QUANTITY OF AIR, REGARDLESS OF LOAD ON THE ENGINE.

COMPRESSION STROKE

ON UPSTROKE OF PISTON, VALVES ARE CLOSED AND MIXTURE IS COMPRESSED, USUALLY FROM 110 TO 150 PSI, DEPENDING ON COMPRESSION RATIO OF ENGINE.

ON UPSTROKE OF PISTON, VALVES ARE CLOSED AND AIR IS COMPRESSED TO 400 TO 600 PSI.

POWER STROKE

COMPRESSED FUEL-AIR MIXTURE IS IGNITED BY ELECTRIC SPARK. HEAT OF COMBUSTION CAUSES FORCEFUL EXPANSION OF CYLINDER GASES AGAINST PISTON, RESULTING IN POWER STROKE.

HIGH COMPRESSION PRODUCES HIGH TEMPERATURE FOR SPONTANEOUS IGNITION OF FUEL INJECTED NEAR END OF COMPRESSION STROKE. HEAT OF COMBUSTION EXPANDS CYLINDER GASES AGAINST PISTON, RESULTING IN POWER STROKE.

EXHAUST STROKE

UPSTROKE OF PISTON WITH EXHAUST VALVE OPEN FORCES BURNED GASES OUT, MAKING READY FOR ANOTHER INTAKE STROKE.

UPSTROKE OF PISTON WITH EXHAUST VALVE OPEN FORCES BURNED GASES OUT, MAKING READY FOR ANOTHER INTAKE STROKE.

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Figure 8-1.—Comparison of sequence of events in diesel and gasoline 4-cycle engines.

more practical with the development of improved, lightweight, high-speed automotive diesel engines.

COMBUSTION CHAMBER DESIGN

Several types of combustion chambers are used in modern diesel engines. They are designed to create turbulence in the cylinder in order to mix the air and fuel more effectively. All modern combustion chambers may be classified under one of four designs: open type, precombustion type, turbulence chambers, and energy cells.

Open Combustion Chamber

The open combustion chamber (fig. 8-2) is the simplest form of chamber. As the piston comes up on the compression stroke, the turbulence is generated by the design of the cylinder head and the piston crown. The injector is mounted in the cylinder head so that the end extends slightly into the cylinder. The fuel is injected directly into the combustion space formed by the top of the piston and the cylinder head. The open chamber requires higher injection pressures and a greater degree of atomization than the other types of combustion chambers to obtain the proper air-fuel mixing. To equalize combustion in the combustion chamber, it uses the multiple orifice-type injector tip for effective penetration and angle of spray.

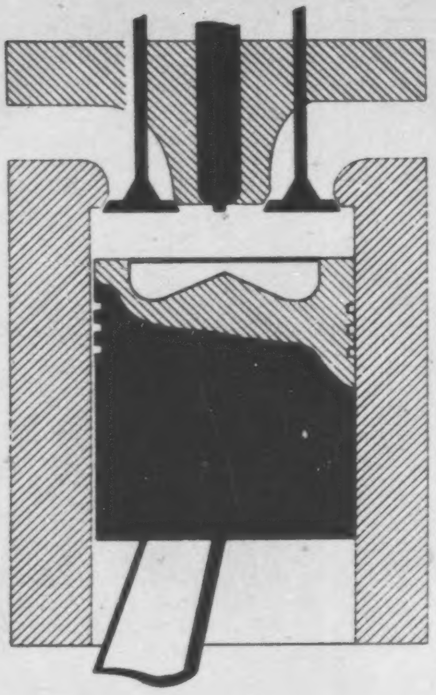

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Figure 8-2.–Diesel engine open combustion chamber.

Precombustion Chamber

Figure 8-3 shows a diagram of a precombustion chamber. This chamber is usually separate from the cylinder head, but is screwed or pressed into the opening provided in the cylinder head. The precombustion chamber is water-cooled because it extends through the water jacket and into the bottom of the cylinder head. It must be sealed at both ends to prevent water leakage.

As the piston moves up on the compression stroke, a small part of the compressed air enters

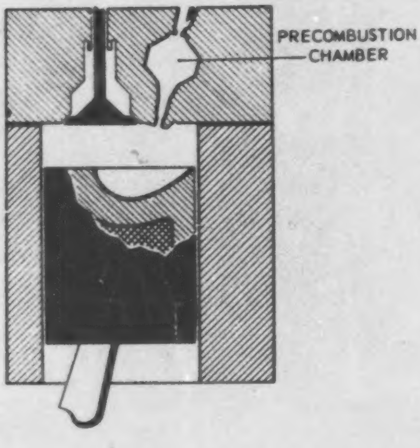

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Figure 8-3.–Diesel engine precombustion chamber.

the precombustion chamber where it swirls rapidly within a small space. The fuel nozzle is of the single hole type and is mounted into the precombustion chamber. Since fuel is injected from a single hole nozzle it is only slightly atomized, and depends on the highly turbulent air for further atomization and ignition. Because of the high pressures generated inside the precombustion chamber by the small amount of air and fuel as it begins to burn, the remaining fuel is atomized and vaporized as it is injected into the precombustion chamber, and is then forced into the main combustion space to complete the combustion process.

Turbulence Chamber

The turbulence chamber (fig. 8-4) is similar in appearance to the precombustion chamber, but its function is different. There is very little clearance between the top of the piston and the head, so that a high percentage of the air between the piston and the cylinder head is forced into the turbulence chamber during the compression stroke. The chamber is usually spherical, and the opening through which the air must pass becomes smaller as the piston reaches the top of the stroke. This increases the velocity of the air in the chamber. This turbulence speed is about 50 times crankshaft speed. Fuel injection is timed to occur when the turbulence in the chamber is greatest. This ensures a thorough mixing of the fuel and air, causing the greater part of combustion to take place in the turbulence chamber. The pressure created by expansion of the burning gases is the force that drives the piston downward on the power stroke.

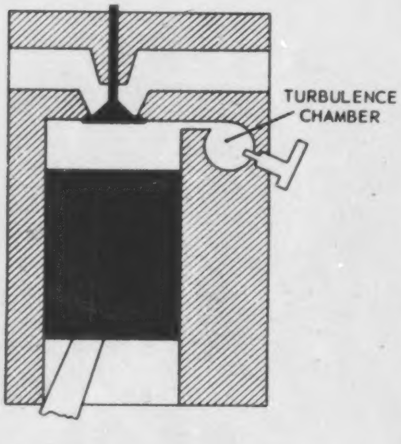

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Figure 8-4.—Diesel engine turbulence combustion chamber.

Energy Cell

The energy cell combustion chamber consists of a main combustion chamber located in the cylinder head with an antechamber on the opposite side of the combustion chamber from the injection nozzle. This type of energy cell is called the Lanova Energy Cell. It is generally used in high-speed diesel engines, usually with less than a 5-inch bore.

The energy cell creates a high turbulence within the main combustion chamber by sending a high velocity mixture of fuel and air into the combustion chamber when the piston starts the downward position of the expansion or exhaust stroke. This tends to promote completion of combustion very quickly, and thus gives good economy.

FUEL SYSTEM

The fuel system of a diesel engine consists of a supply tank, filters, supply pump, lines, and injection system. The supply tank and fuel lines are similar to those used for gasoline engines.

Fuel for a diesel engine is drawn from the supply tank through the primary fuel strainer (filter) and enters the supply fuel pump on the inlet side. The pump pressurizes the fuel, forcing it through a filter and through the fuel lines to the fuel injection system. The fuel is forced to the injectors and through small spray tip orifices (atomizing the fuel) in the combustion chamber.

FUEL SUPPLY PUMP

Fuel injection pumps must be supplied with fuel oil under pressure because they have insufficient suction ability. All diesel injection systems require a supply pump to transfer fuel from the supply tank, through the filters and lines, to the injection pumps. Supply pumps in use on diesel engines today are the gear and vane pumps.

Gear Pump

The gear pump (fig. 8-5) is the type commonly used on diesel engines. This pump has two spur gears which mesh together—one the driving gear and the other the driven gear. Clearances between the gear faces and the casing are only a few thousandths of an inch. When the gears turn, liquid in the spaces between the unmeshed teeth, at the suction side of the pump, is carried by the teeth towards the sides. Then the liquid is trapped between the tooth pockets and the casing and carried through to the discharge side of the pump. Liquid entering the discharge side cannot return to the suction side because the meshing teeth at the center force the liquid out of the tooth pockets.

Vane Pump

In the vane-pump (figs. 8-6 and 8-7), a steel rotor and shaft one end supported in the pump mounting flange and the other end in the pump cover, revolve in the body, the bore of which is eccentric to the rotor. Two sliding vanes are placed 180 degrees apart in slots in the rotor, and are pressed against the body bore by springs in the slots. When the shaft is rotated, the vanes pick up fuel at the inlet port and carry it around the body to the outlet side, where the fuel is discharged. Pressure is produced by the wedging action of the fuel as it is forced toward the outlet port by the vane. A spring-loaded relief valve is provided in the cover of the pump, connecting the inlet and outlet ports. This valve opens at a pressure of approximately 55 psi. Its purpose is to relieve excessive pump pressure which will build up if fuel lines or filters become clogged. When the valve opens, fuel passes from the discharge side (pressure side) to the suction side of the pump.

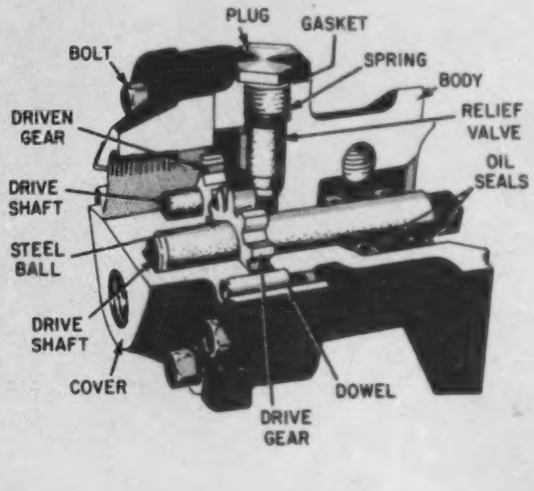

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Figure 8-5.—Typical gear fuel pump assembly.

FUEL INJECTION AND COMBUSTION

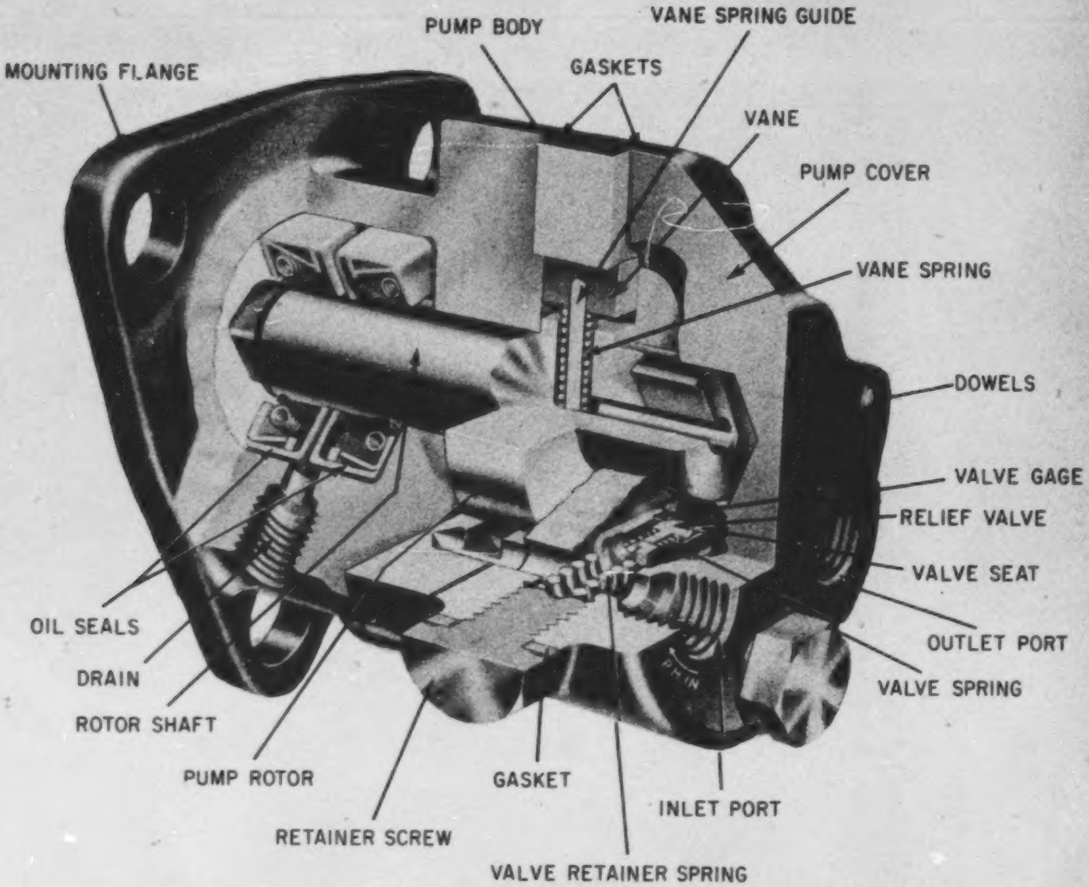
Diesel fuel injection systems must accomplish five particular functions:

1. Meter or accurately measure the correct amount of fuel injected.
2. Time the fuel injection to start and stop at the proper time.
3. Control the rate of injection.
4. Atomize or break up the fuel into fine particles according to the type of combustion chamber.
5. Properly distribute the fuel in the combustion chamber.

All five of these functions are necessary for complete and efficient combustion.

Metering

Accurate metering or measuring of fuel means that, for the same fuel control setting, the same quantity of fuel must be delivered to each cylinder for each power stroke of the engine. Only in this way can the engine operate at uniform speed with a uniform power output. Smooth engine operation and an even distribution of the load between the cylinders


PUMP BODY
VANE SPRING GUIDE
MOUNTING FLANGE
GASKETS
VANE
PUMP COVER
VANE SPRING
DOWELS
VALVE GAGE
RELIEF VALVE
VALVE SEAT
OUTLET PORT
VALVE SPRING
OIL SEALS
DRAIN
ROTOR SHAFT
PUMP ROTOR
GASKET
INLET PORT
RETAINER SCREW
VALVE RETAINER SPRING

81.149

Figure 8-6.—Cutaway view of vane-type fuel pump.

depend upon the same volume of the fuel being admitted to a particular cylinder each time it fires; and upon equal volumes of fuel being delivered to all cylinders of the engine. The fuel is forced into the cylinder by direct pressure on the fuel itself (mechanical injection).

Timing

In addition to measuring the amount of fuel injected, the system must properly time injection to ensure efficient combustion so that maximum energy can be otained from the fuel. When fuel is injected too early in the cycle, preignition can occur, causing the engine to lose power and have low exhaust temperature. Excessive delay, on the other hand, will cause high exhaust temperature, and possibly cause damage to the pistons, rods, and bearings. Also, this condition will cause a loss of fuel by wetting the cylinder walls and piston heads, resulting in smoke in the exhaust and poor fuel economy. When fuel is injected too late in the cycle, all the fuel will not burn until the piston has traveled

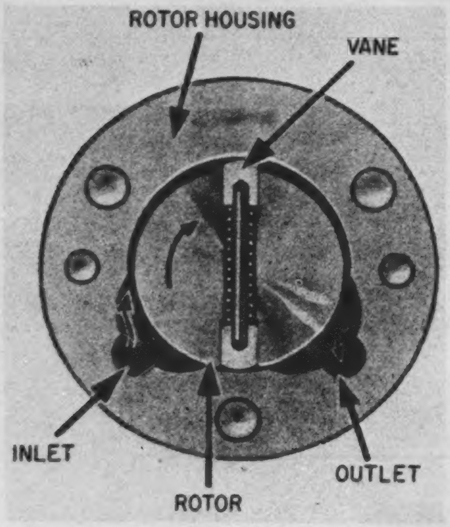


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Figure 8-7.–Vanes and rotor in housing of a vane-type fuel pump.

well past top center. When this happens, the engine does not develop its maximum power, the exhaust is smoky, and the fuel consumption is high.

Injection Rate Control

A fuel system must also control the rate of injection. The rate at which fuel is injected determines the rate of combustion. The rate of injection at the start should be low enough that excessive fuel does not accumulate in the cylinder during the initial ignition delay (before combustion begins). Injection should proceed at such a rate that the rise in combustion pressure is not too great, yet the rate of injection must be such that fuel is introduced as rapidly as possible in order to obtain complete combustion. An incorrect rate of injection affects engine operation in the same way as improper timing. When the rate of injection is too high, the results are similar to those caused by a too early injection; when the rate is too low, the results are similar to those caused by a too late injection.

Atomization of Fuel

As used in connection with fuel injection, atomization means the breaking up of the fuel, as it enters the cylinder, into small particles which form a mist-like spray. Atomization of the fuel must meet the requirements of the type of combustion chamber in use. Some chambers require very fine atomization; others function with coarser atomization. Proper atomization makes it easier to start the burning process, and ensures that each minute particle of fuel is surrounded by particles of oxygen with which it can combine.

Atomization is generally obtained when the liquid fuel, under high pressure, passes through the small opening (or openings), in the injector or nozzle. As the fuel enters the combustion space, high velocity is developed because the pressure in the cylinder is lower than the fuel pressure. The created friction, resulting from the fuel passing through the air at high velocity, causes the fuel to break up into small particles.

Distribution

A fuel injection system must increase the pressure of the fuel enough to overcome compression pressures and to ensure proper distribution of the fuel injected into the combustion space. Proper dispersion is essential if the fuel is to mix thoroughly with the air and burn efficiently. While pressure is a chief contributing factor, dispersion of the fuel is influenced, in part, by atomization and penetration of the fuel. (Penetration is the distance through which the fuel particles are carried by the motion given them as they leave the injector or nozzle.)

If the atomization process reduces the size of the fuel particles too much, they will lack penetration. Too little penetration results in the small particles of fuel igniting before they have been properly distributed or dispersed in the combustion space. Since penetration and atomization tend to oppose each other, a compromise in the degree of each is necessary in the design of fuel injection equipment, particularly if uniform distribution of fuel within the combustion chamber is to be obtained.

Fuel Injector

The fuel injector is mounted in the cylinder head or combustion chamber with the spray tip or injector nozzle protruding into the combustion chamber similar to a spark plug on a gasoline engine. The injection system combines all the operations necessary to provide complete fuel injection to each cylinder. Within the injection system the fuel is metered, the rate of injection is controlled, injection is timed, high pressure necessary for distribution is created or controlled, and atomization occurs.

In most diesel engines the fuel is delivered to the cylinders by a mechanical injector system that can be divided into two main types—the distribution pressurized type and the unit injector type.

The distribution pressurized types have either a high pressure pump that discharges fuel in a common header to which each fuel injector nozzle is connected by tubing, or individual high pressure pumps for each cylinder connected to the fuel injector nozzle by tubing. In either case the injector nozzle does not furnish the pressure necessary to overcome the cylinder pressure and spray the fuel into the cylinder, but only meters and times the fuel injection. A spring-loaded bypass valve on the header or on the line to the injector nozzle maintains a constant pressure and returns the excess fuel to the supply tank.

The spray or injection nozzle extends from the top of the cylinder head down into the combustion area. It consists of a multihole spray tip, a valve seat, and a needle valve extending the full length of the nozzle and head to its seat which is supported by a spring. The high pressure is conducted from the fuel line to the spray tip immediately above the valve seat. When the valve needle is lifted vertically from its seat, fuel is sprayed into the combustion chamber.

In both the distribution pressurized type and the unit injection type of fuel injection systems for diesel engines, the pumps and injector nozzle are operated by cam-actuated mechanisms similar to the valve lifting mechanisms of internal combustion engines.

The unit injector type of fuel injection has the injection nozzle and pressurization pump all in one unit that is attached to the cylinder head. The delivery fuel pump supplies the fuel to the unit; and it delivers enough pressure to overcome the cylinder pressure, meters the fuel, times the delivery, controls the rate of injection, and atomizes and distributes the fuel in the combustion chamber. Usually water circulation passages keep the lower part of the unit cool. Figure 8-8 illustrates and lists the part of a unit injector.

MAINTENANCE.—When fuel injector troubles are suspected, and before removing the injectors for shop testing, it is a good practice to check the injectors and attempt to isolate those which are causing the trouble. First operate the engine at a speed at which the defect is more pronounced. On engines that have a pump and nozzle fuel system, loosen the fuel line connection at each injector pump one at a time to deactivate the cylinders. To deactivate the cylinders for engines with unit injectors, the plunger mechanism must be depressed.

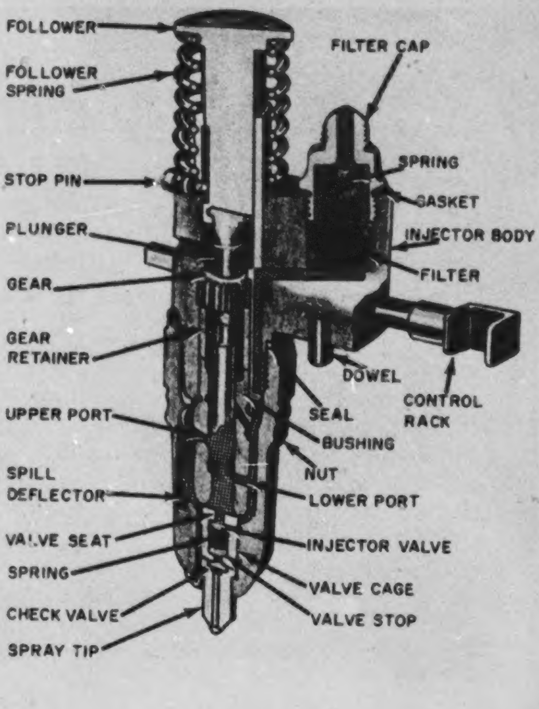

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Figure 8-8.—Unit injector.

When an injector is found in which deactivation caused little or no change in the irregular operation of the engine, the injector is probably causing the trouble and needs to be removed and tested further. It is seldom that one injector alone is responsible for all the trouble; therefore, do not stop testing when the first faulty injector is detected but check all injectors by the deactivation test.

Unless special servicing equipment and repair instructions are available, defective nozzles and pumps are usually exchanged for new ones. In an emergency, if the parts of the injector are not too badly worn, they can be returned to a serviceable condition with minor adjustments and a thorough cleaning. Always consult the manufacturer's recommeded procedures for disassembly and adjustment of the injector.

Remove the faulty injector from the equipment and take it to the shop. The injector is too delicate a piece of equipment to be disassembled and reassembled in the field. If a clean workbench is not available, cover the available bench with smooth-finish wrapping paper. To prevent mixing of parts, disassemble only one injector at a time. To prevent damage, exercise care in disassembling the parts. Inspect and clean all parts as they are disassembled. Clean diesel fuel of the same type used in the engine should first be used for cleaning. Dry cleaning fluid may be used to clean parts; however, if used, dip the parts in diesel fuel immediately after cleaning, to prevent moisture from the hands from marring the highly polished surfaces.

Carbon may be scraped from the outside of the nozzles, but be careful not to mar the edges of the orifices. Reaming tools and special drills are usually provided by the manufacturer for cleaning spray nozzle holes (orifices). No drills other than those supplied or recommended by the manufacturer should be used. In performing reaming or scraping operations, remove only the foreign matter. Be particularly careful not to burr the metal. After repair and reassembly of the injector, it should be checked for leakage and proper opening pressure by utilizing an injection tester.

FUEL FILTERS

Fuel filters are built into the fuel supply systems of diesel engines to filter any abrasive impurities that may be in the fuel. These impurities may have been difficult to eliminate during the process of refining, or they may enter the fuel tank through careless refueling. Whatever the source, these impurities must be removed to protect the closely fitted parts in the pumps and nozzles.

Must diesel engines have two filters in the fuel supply system. The primary (coarse) filter (sometimes called strainers) is usually located between the supply tank and the fuel supply pump, and the secondary filter, between the fuel supply pump and the injector or injector pump. Additional filtering elements are frequently installed in the injection pump or in the injectors.

Diesel fuel oil filters are referred to as full-flow filters, since all the fuel must pass through the filters before reaching the injection system. Filters must be inspected regularly and cleaned or replaced, if their maximum efficiency is to be maintained. All metal disc filters and some cloth bag filters are cleanable, but most cloth or fabric elements must be replaced when they become dirty.

Metal Disc Filter

The metal disc filter shown in figure 8-9 is made of a series of laminated discs placed within a large bowl which acts as a settling chamber for the fuel and encloses the discs or strainer assembly. Fuel enters the filter at the top inlet connection and, flowing down, goes between the discs, and then up a central passage to the outlet connection at the top. Dirt and foreign matter cannot pass between the discs and are deposited at the outer rim. The clearance between the discs, measured in microns, is small enough to prevent the passage of water. This is possible because water, when present in gasoline or oil, forms small globules that are too large to pass between the discs. The filter shown in figure 8-9 is the same as the one mentioned above except that a cleaning knife is added. Solids larger than 0.005 inch remain on the outside of the

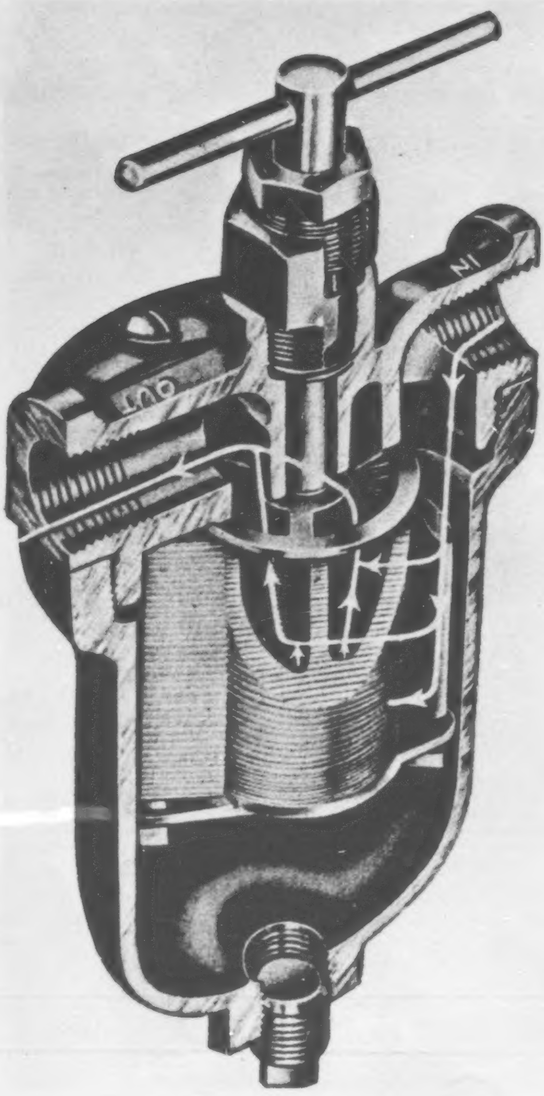

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Figure 8-9.—Metal disc fuel filter.

element, and the cleaning knife scrapes these deposits off the filtering discs. The solids fall to the bottom of the filter housing, where they can be removed through the drain plug hole. A ball relief valve (if used) in the filter cover enables the diesel fuel oil to bypass the filter element if the discs become clogged. A diesel oil filter usually has an air vent for releasing any air which might accumulate in the filter during engine operation.

Fabric Filter

Fabric filters, because of their greater filtering qualities, are used principally as main filters for protecting the fuel injection system. Many fuel filters now in use require changing of the filtering element; however, the bag-type filter shown in figure 8-10 is more desirable because the element can be cleaned. The filtering medium is a large bag of close, evenly woven, lintless, acid-resisting material.

AIR INTAKE SYSTEM

Much of the information dealing with parts and systems of the diesel engine also applies to

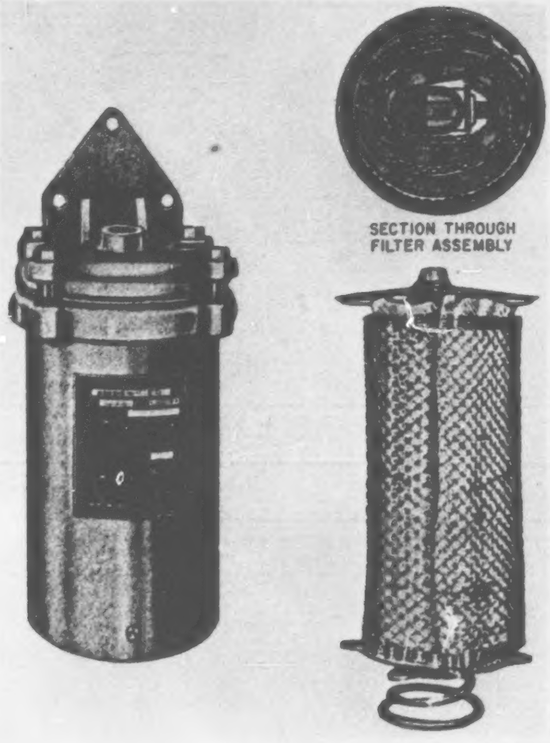

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Figure 8-10.—Bag-type fuel filter.

the gasoline engine. The air intake system is no exception. However, the intake event in the cycle of operation of a gasoline engine includes the admission of air and fuel to the cylinder as a mixture. For this reason the intake system of a gasoline engine differs, in some respects, from that of a diesel engine.

In some four-stroke cycle diesel engines, air is forced by atmospheric pressure into the cylinder through valves to displace the partial vacuum created by the pistons movement away from the cylinder head. However, in all two-cycle and many supercharged four-cycle engines, air is forced into the cylinder by a blower (supercharger) or by a turbocharger. The turbocharger is usually an exhaust-driven centrifugal type blower.

The main job of the blower, supercharger, or turbocharger, is to supply the cylinder with fresh air for combustion so the engine can burn more fuel and develop more horsepower than if it were fed through valves by atmospheric pressure. The blower, on two-cycle engines, consists of two hollow three lobed rotors enclosed in a housing on the side of the cylinder block. They revolve without touching each other, but with very close clearance. At maximum engine speed the blower is capable of supplying a continuous discharge of fresh air at a pressure of 7 psi.

Figure 8-11 illustrates how the air is forced into the cylinder by the blower through the intake ports of the cylinder lines as they are uncovered by the downward stroke of the piston. This forced air action forces out the burned gases through the exhaust valve openings and helps to cool the internal parts of the engine, particularly the exhaust valves. To improve combustion, the intake ports are angled to give the incoming air a circular motion (turbulence) during the compression stroke.

Air Cleaners

Most aviation support equipment is used around areas where activity constantly stirs up particles of dirt and dust. These particles may cause internal damage if they enter the engine as air enters. Therefore, diesel engines are equipped with air cleaners or filters to eliminate dust and dirt particles. There are two distinct types of air cleaners used on diesels–the dry type and the oil-bath or wet-type.

DRY-TYPE AIR CLEANERS.–The dry-type air cleaner draws the air through a cleaning element, which may consist of cotton fabric, wire screens (especially wound copper crimp), or metal wool saturated with oil. The cleaning element collects the dust and other abrasive particles from the air as it passes down through the central duct into the blower. The hollow housing supporting the cleaning element also serves as a silencer to lessen the whining noise of the air entering the air cleaner.

OIL-BATH OR WET-TYPE AIR CLEANER.–The oil-bath or wet-type air cleaner is similar to the dry-type cleaner. The main difference is that the wet type contains an oil reservoir in the air cleaner bowl, and the air is directed downward into the oil bath where most of the harmful particles are removed. The air then continues upward through the cleaning element (metal wool), which removes the finer harmful particles not removed by the oil. From this point, the air continues down the central duct into the blower and engine.

STARTING SYSTEMS

At the beginning of this chapter it was stated that the pressure and temperature inside the combustion chamber must be high enough to ignite the fuel-air mixture when the fuel is injected. By turning the engine over with the starter at a relatively high speed (in comparison to the speed of the starter of a gasoline engine) the desired pressure in the combustion chamber is achieved. Since the engine and fuel are cold before starting, the problem is to compensate for the lack of high temperature necessary to ignite the fuel in the combustion chamber. In small diesel engines being started in temperatures above freezing, the electric starter turns the engine fast enough to make the pressure high enough to cause the fuel-air mixture to ignite. To start larger diesel engines and all diesel engines during cold weather, other starting systems or starting assists must be employed, or the engine must be preheated.

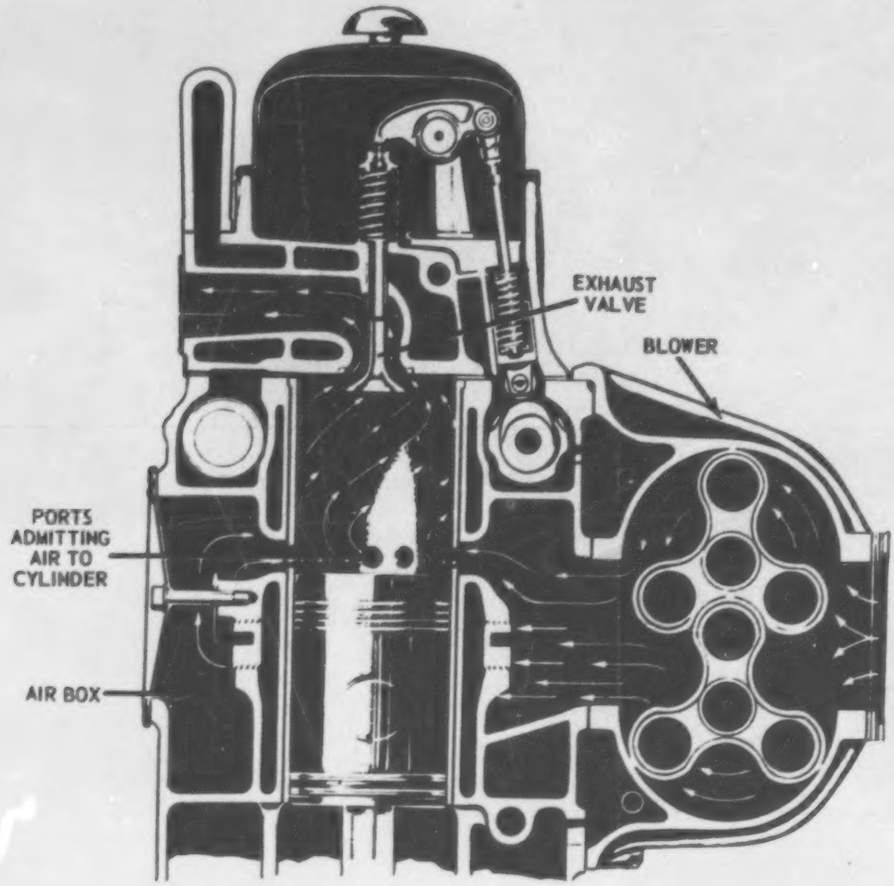

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Figure 8-11.—Air intake system through blower and engine (two-cycle).

The diesel engines used in aviation support equipment are started by either an electrical system consisting of an electrical storage battery and a cranking motor, or a hydraulic combination consisting of a high pressure accumulator and a hydraulic oil-driven motor. The electrical system is similar to the system used to start gasoline engines, except that the cranking motor turns the diesel engine at a relatively high speed.

The hydraulic starting motor receives its motive power from a pressurized accumulator. The accumulator is charged with hydraulic fluid from a reservoir, either by means of a hand pump or an engine-driven hydraulic pump while the engine is operating. The accumulator has the ability to store the fluid under pressure without loss of pressure for long enough to permit starting after overnight parking. The hand pump is used to bring the accumulator pressure up to the starting requirement when necessary.

A starting valve is used to release the accumulator pressure to the cranking motor. The starter valve is a dual orifice type. A smaller orifice provides fluid pressure for initially engaging the drive pinion, while the larger orifice, opened on the second phase of the starting valve handle movement, cranks the engine. The starting valve handle is initially opened only far enough to engage the starter. As soon as the starter is engaged, the handle is moved all the way open to provide the necessary pressure to turn over the engine with the cranking motor.

The starting assists (called starting aids) used to start a diesel engine during cold weather are two types–the fluid primer type and the glow plug type. The primer type utilizes either a sealed cartridge or can. The cartridge or can contains a highly volatile fluid to be injected in the air intake system to assist in igniting the diesel fuel injected into the combustion chamber. The starting fluid is released into the intake manifold as starting is initiated. By lowering the ignition temperature of the fuel-air mixture, the starting fluid permits the buildup of pressure in the combustion chamber to raise the temperature of the fuel-air mixture high enough to reach ignition temperature.

Figure 8-12 illustrates a fluid primer starting aid. The cartridge is inserted in the container and pierced by the shaft. As the fluid is needed the pump is operated to supply the fluid to the intake manifold.

The glow plug starting assist is an electrical heating element installed next to each fuel injector to preheat the injector and the combustion chamber. The heating element is supplied with current from the battery. The glow plug is used for the period of time specified in the manufacturer's starting instructions and then the starter is energized to start the engine.

Maintenance and repair of the hydraulic system of the hydraulic starting motor are responsibilities of the ASH. To repair either the hydraulic or the electric starting motor, the motor is usually removed from the engine as a unit and a replacement installed as was described for gasoline engines. Be sure to consult the manufacturer's maintenance manual before attempting repair of either type starter.

LUBRICATION SYSTEM

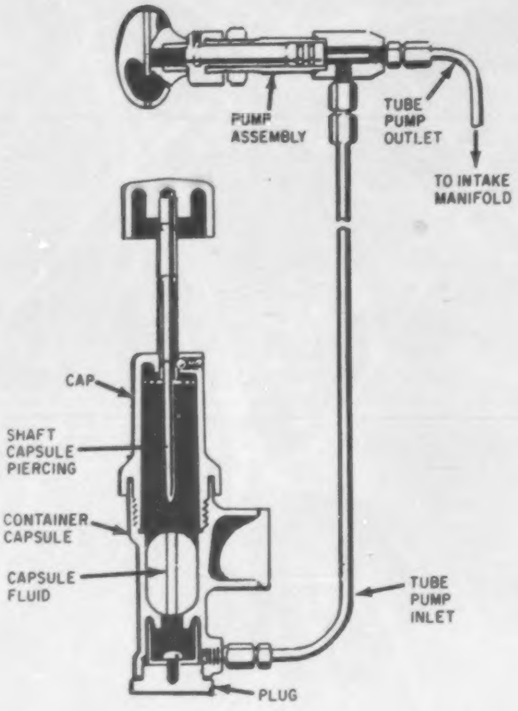

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Figure 8-12.–Fluid primer starting aid.

One of the most important items contributing to the long life of an engine is that of proper lubrication. The main job of the lubrication system is to overcome friction between moving parts. If this friction is not eliminated, moving parts will melt, fuse, or seize after a very short period of engine operation.

An adequate lubricating system has been provided to meet a wide variety of working conditions of our modern diesel and gasoline internal combustion engines. It is up to you, the MECHANIC, to keep this system functioning properly.

The major difference between the lubrication systems of the gasoline and the diesel engine is that the latter normally contains an oil cooler (fig. 8-13). The oil pump draws the oil from the oil pan, through the strainer, and to the oil cooler. After leaving the oil cooler (where the water from the cooling system removes the heat from the oil), the oil enters the main gallery

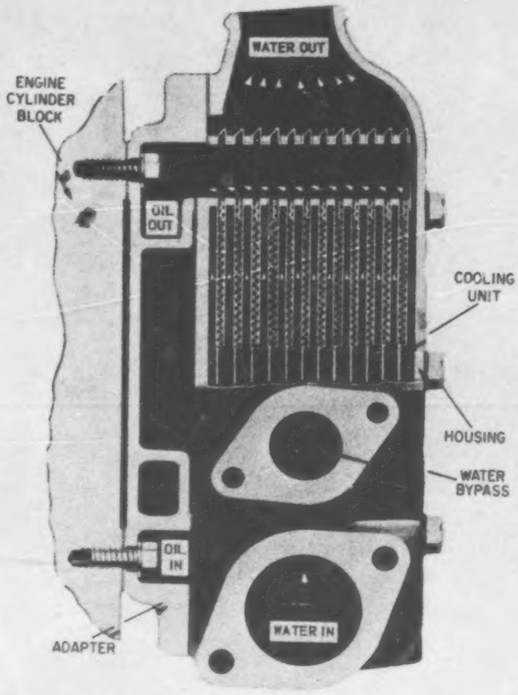

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Figure 8-13.—Sectional view of an oil cooler.

(constantly under pressure) in the cylinder block; from here it is distributed through small holes and openings to the various moving parts and bearings.

COOLING SYSTEM

There are two types of cooling systems employed in diesel engines. One type uses the principle of the heat exchanger. The heat exchanger is a device that transfers heat from one fluid or liquid to another. (The oil cooler mentioned earlier is an example of a heat exchanger.)

The most common type of diesel cooling system is a radiator and cooling fan (fig. 8-14). Heat is removed by circulating water through water jackets surrounding the hottest parts of the engine (cylinders and the full length of piston travel). Heat is transferred to the water while the water is being pumped through the passages of the cylinder block and up into the cylinder head. The water then passes through the upper hose connection, and the heated water is carried into the radiator. As the water flows down through the radiator the heat is removed by a stream of air forced through the radiator by the fan. From the bottom of the radiator, the water flows through the lower hose connection to the pump, where it is again forced into the water jackets to repeat the cooling cycle.

MALFUNCTIONS

Satisfactory diesel engine operation depends primarily on injection of the proper amount of fuel at the right time and the presence of an adequate supply of air compressed to a sufficiently high pressure. Lack of power, uneven running, excessive vibration, stalling at idle speed, and hard starting are malfunctions that may be caused by low compression, faulty injection in one or more cylinders, or lack of sufficient air. Testing and repair of fuel injectors have been covered previously in this chapter. Investigation of some other causes of malfunctions is covered here.

When faulty fuel injection is suspected, the fuel supply system should be checked by inspection of the strainer and filter to ensure that they are not clogged and permitting contaminated fuel to cause the fuel pump or injectors to malfunction. Be sure that all line connections between the fuel tank and the injectors are tight so that no air will be drawn into the fuel system. Consult the engine manufacturer's maintenance instructions for the proper tests of the supply system.

Poor combustion and lack of power will result from excessive restriction of the air intake, which affects the flow of air to the cylinders. An obstruction in the air inlet system, or dirty or damaged air cleaners may result in a high degree of intake restriction. The air inlet system can be visually inspected and obstructions removed. The air cleaners can be inspected and cleaned or replaced to remove this discrepancy. A pressure gage can be used to check for air

81.371

Figure 8-14.–Cooling system for International engine.

intake restriction. Be sure to consult the manufacturer's maintenance instructions for desired pressure and method of using the pressure gage.

Diesel cylinder compression is checked in a manner similar to that for gasoline engines. Since high compression is one of the requirements for proper combustion in a diesel engine, the compression pressure in any cylinder should not be less than the minimum prescribed for the particular engine at the altitude tested. Consult the manufacturer's instructions for the correct pressure. Low cylinder pressure may result from piston rings being stuck or broken. Another cause may be compression leaking past the cylinder head gaskets, the valve seats, the injectors, or a hole in the piston. Complete or partial dismantling of the engine may be necessary to isolate the cause if not determined by leakage tests.

DANGER OF EXCESSIVE SPEED

Engines which are maintained in proper operating condition seldom reach speeds above those for which they are designed. However, there may be times when speeds become too high. Operation of an engine at excessive speeds is extremely dangerous. If engine speed is high enough, the high inertia and centrifugal forces developed may cause parts to become seriously damaged, or even to fly apart. Therefore, it is essential that you know why an engine may reach a dangerously high speed, and how it may be brought under control when too much speed occurs.

Causes of Excessive Speed

In some 2-stroke cycle engines, lubricating oil may leak into the cylinders as a result of leaky blower seals or broken piping. Even though the fuel is shut off, the engine may continue to operate, or even run away, as a result of this combustible material coming from the uncontrolled source. Engines in which lubricating oil may accumulate in the cylinders are generally equipped with an automatically operated mechanism which shuts off the intake air at the inlet passage to the blower. If no air shut-off mechanism is provided, and shutting off the fuel will not stop an engine which is overspeeding, anything which can be placed over the engine's air intake to stop air flow, such as a piece of canvas or even a pair of dungarees, will stop the engine.

Excessive engine speeds more commonly result from an improperly functioning regulating governor than from any other cause. The usual method of accomplishing an emergency shut down when the regulating governor fails to function properly is to shut off the fuel oil supply to the cylinders. If this fails to slow the engine or stop it, the air supply to the engine must be cut off.

CAUTION: Do not risk personal injury to stop an overspeeding engine when all normal means have failed.

STOPPING FUEL SUPPLY

Shutting off the fuel supply to the cylinders of an engine may be done in various ways. The fuel control mechanism may be forced to the NO FUEL position; the fuel line may be blocked by closing a valve; the pressure in the fuel injection line may be relieved by opening a valve; or the mechanical movement of the injection pump may be prevented. These methods of shutting off the fuel supply may be done either manually or automatically.

OVERSPEED SAFETY DEVICES

Automatic operation of fuel and air control mechanisms is accomplished by overspeed safety devices. As emergency controls, these safety devices operate only in the event the regular speed governor fails to maintain engine speed within the maximum design limit. Devices which function to bring an overspeeding engine to a full stop by completely shutting off the fuel or air supply are generally called OVERSPEED TRIPS. Devices which function to reduce the excessive speed of an engine, but allow the engine to operate at safe speeds, are called OVERSPEED GOVERNORS.

All overspeed governors and trips depend upon a spring-loaded centrifugal governor element for their operation. In overspeed devices, the spring tension is great enough to overbalance the centrifugal force of the weights until engine speed rises above the desired maximum. When an excessive speed is reached, the centrifugal force overcomes the spring tension and operates the mechanism which stops or limits the fuel or air supply.

GOVERNORS AS SAFETY DEVICES

When a governor serves as the safety device, actual operation of the fuel or air control mechanism by centrifugal force may be brought about directly, as in a mechanical governor, or indirectly, as in a hydraulic governor. In the case of an overspeed trip, the shutoff control is operated by a power spring. The spring is placed under tension when the trip is manually set, and held in place by a latch. If the maximum speed limit is exceeded, a spring-loaded centrifugal weight moves out and trips the latch, allowing the power spring to operate the shutoff mechanism.

INSPECTIONS

PREOPERATIONAL

To obtain the longest life and best performance from a diesel engine, the operator must adhere to the published schedule of preoperational inspection and preventive maintenance. These appear on Maintenance Requirement Cards for the engine or the equipment having the engine as a power source. They also appear in the operator's instructions published by the manufacturer. When first using the diesel engine after overhaul or when new, the operator should carefully read and follow the instructions of the manufacturer. Attempting to run the engine before complying with these instructions may result in serious damage to the engine.

PERIODIC

Any periodic inspection or preventive maintenance performed on diesel engines should be done in accordance with the Maintenance Requirement Cards for the engine or equipment on which it is used.

CHAPTER 9

CHASSIS SYSTEMS

Many of the vehicles maintained by Aviation Support Equipment Technicians (M) are equipped with steering mechanisms. The purpose of this chapter is to familiarize the ASM with the components and maintenance of typical steering systems and the related suspension systems.

STEERING COMPONENTS

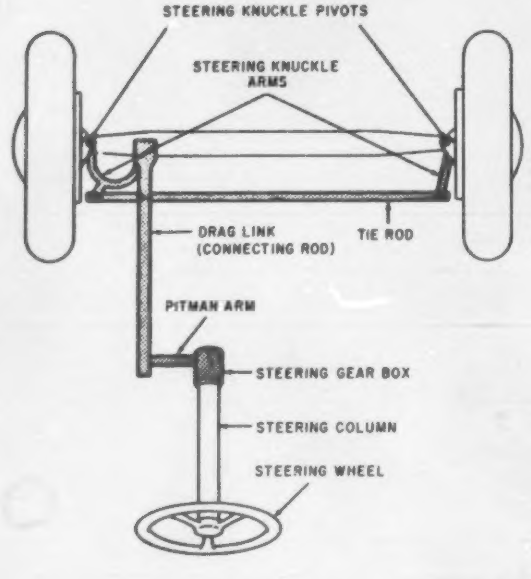
Though steering may be a simple operation, the steering mechanism is rather complex. Figures 9-1 and 9-2 show a diagram of a steering mechanism and an illustration of an actual steering system.

All steering mechanisms have the same basic parts. The steering linkage ties the front wheels together and connects them to the steering gear case at the lower end of the steering column, which in turn connects the gear case to the steering wheel.

The arms and rods of the steering linkage have ball or ball and socket ends to provide a swivel connection between them. These jointed ends are provided with grease fittings, dust seals or boots, and many of them have end-play adjustment devices. These joints and devices must be adjusted and lubricated regularly.

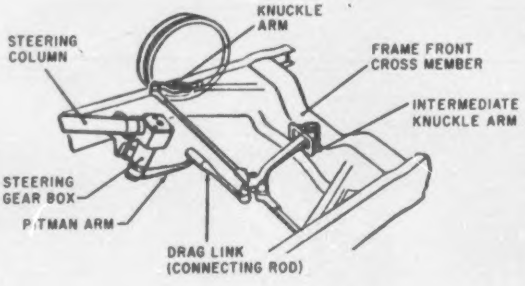
The arms, rods, and joints of steering linkages in your equipment may be arranged differently from those shown in figure 9-1, but you will find them in the same general location in the front or rear and underneath the vehicle.

The tie-rod, for example, is usually located behind the axle and keeps the front wheels in proper alignment. To provide for easier steering and maximum leverage, the tie-rod may be


STEERING KNUCKLE PIVOTS
STEERING KNUCKLE ARMS
DRAG LINK (CONNECTING ROD)
TIE ROD
PITMAN ARM
STEERING GEAR BOX
STEERING COLUMN
STEERING WHEEL

81.254

Figure 9-1.—Diagram of a steering mechanism.


KNUCKLE ARM
STEERING COLUMN
FRAME FRONT CROSS MEMBER
INTERMEDIATE KNUCKLE ARM
STEERING GEAR BOX
PITMAN ARM
DRAG LINK (CONNECTING ROD)

81.255

Figure 9-2.—Steering assembly.

separated into two lengths and connected to the steering gear near the center of the vehicle. (See fig. 9-2.)

The rod (drag link) connecting the steering arm and the pitman arm may be long or short, depending on the installation.

The pitman arm, splined to the shaft extending from the steering gear case, moves forward and backward–depending on which way the wheels are turned. It is approximately vertical when the front wheels are straight ahead. Therefore, the length of the connecting rod is determined by the distance between the steering arm and the vertical position of the pitman arm. Unlike the tie-rods, the length of the connecting rod is not adjustable.

The steering gear case contains the gears that control the movement of the pitman arm and steering linkage. Figure 9-3 shows a typical steering gear assembly, the location of adjustment screw, and the filler plug for gear lubricant.

The principal parts of any steering gear unit are the worm gear and sector. A sector is a portion of a full gear. The sector gear and worm provide a ratio between the number of turns of the steering wheel to one turn of the pitman arm. Because the pitman arm does not turn a complete revolution, only a section of one gear is used in the gear arrangement. The gear ratio of the steering column and the cross shaft which carries the pitman arm varies from 4 to 1 to 18 to 1 in automotive equipment. The high steering gear ratios are used in vehicles which are hard to steer or are slow moving. The low steering gear ratios are used in vehicles that are easy to turn.

To provide easier and more efficient steering, roller and ball bearings have been added to the steering gear units. The design of the worm gear and sector has been changed, and even the names of these parts are different. In figure 9-3, the worm gear is called a cam and the sector is called a stud. These parts work on the same principle as a worm gear and sector.

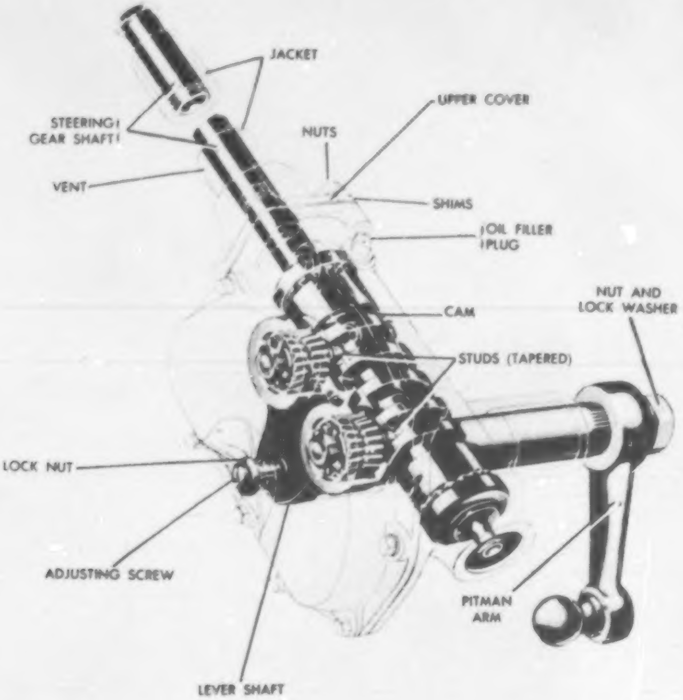
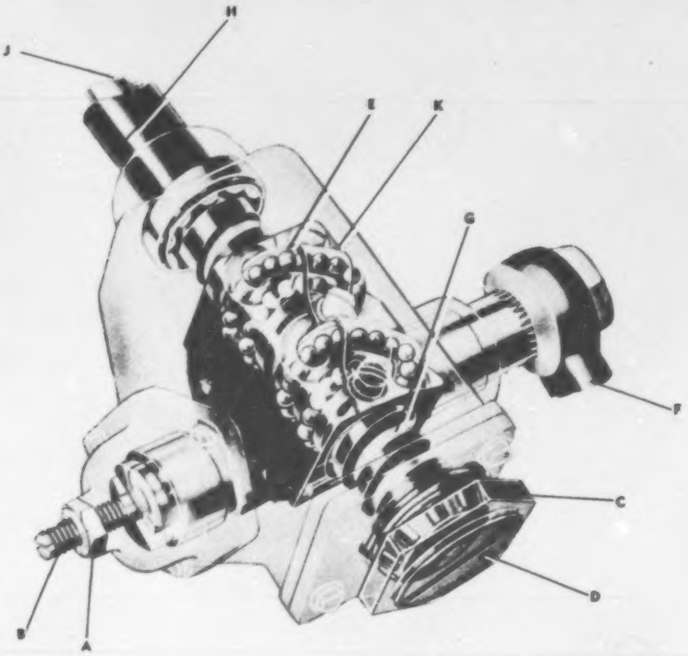


Figure 9-3.—Steering gear unit of the cam and lever type. 81.256

Another form of steering gear is the recirculating ball and nut gear (fig. 9-4). In this assembly the nut is mounted on a continuous row of balls on the worm to reduce friction.

The ball nut is fitted with tubular ball guides to return the balls diagonally across the nut to recirculate them. As the nut moves up and down, the pitman arm turns, and the vehicle's wheels turn with it.

On equipment that is steered by the rear wheels, the steering components and operation are the same except that a longer drag link is necessary to permit the driver to face forward. Because the steering column must be pointed forward to permit the operator to face forward, the distance from the gear box and pitman arm to the steering knuckle arm is greater than on a front steering vehicle. Thus, a longer drag link is required. More and more support equipment is being equipped with rear steering mechanism, especially that designed for aircraft carrier operation.



A. Lash adjuster screw locknut
B. Lash adjuster screw
C. Worm bearing adjusting screw locknut
D. Worm bearing adjusting screw
E. Recirculating balls
F. Pitman arm
G. Worm
H. Jacket
J. Steering gear shaft
K. Ball nut

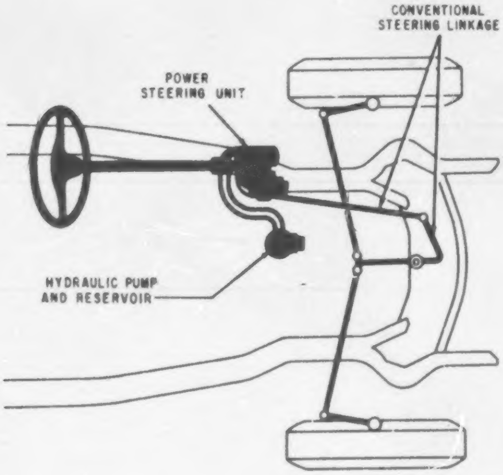
81.257

Figure 9-4.—Recirculating ball-type steering gear.

POWER STEERING

Automotive power steering hydraulic systems consist of three units: the pump (including reservoir), the power cylinder or cylinders, and the control valve. The power steering pump is driven by the engine or an engine-driven accessory by a belt, gears, or a shaft. Lines and hoses connect the three units. All systems are constructed so that the vehicle can be steered manually, should the power steering system fail.

One kind of power steering system has the power cylinder and control valve built into the gear box or case at the base of the steering column. As the steering wheel is turned to the right or left, the control valve directs hydraulic fluid pressure to one side or the other of a piston in the power cylinder that is connected to the pitman shaft and arm. When the driver returns the steering wheel to the neutral or straight ahead position the pressure on both the right and left turn sides of the piston is equalized, and the vehicle travels straight ahead. The pump is usually adjacent to a fluid reservoir where the excess hydraulic fluid is stored. Figure 9-5 is a diagram of this type of system.



227.50

Figure 9-5.—Diagram of a power steering unit.

In the other type of power steering system the control valve is on the pitman arm at the base of the steering column. The power cylinder is mounted on the tie rod between the wheels. In the one shown in figure 9-6, the power cylinder is double acting. When the steering wheel is turned, the pitman arm turns and routes fluid under pressure to one side of the cylinder, which assists in turning the wheels. When the steering wheel is neutral, equal pressure is applied to both sides of the power cylinder.

Since pressure is built up in the power steering system, the fittings, gaskets, and lines used in the system should be inspected frequently for leaks. When a fitting is found leaking, tighten or replace it. Gaskets and packings should be replaced when it is determined that they are leaking or faulty. The level of the fluid in the power steering system should be checked regularly and refilled as necessary. Care should be exercised, when adding fluid, that no foreign matter enters the system to block the control valve and cause the system to malfunction.

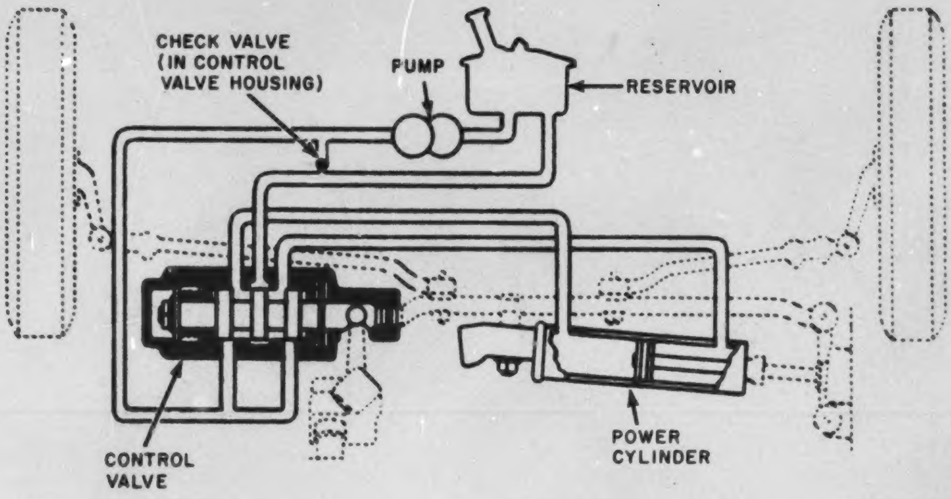
WHEEL ALIGNMENT

Steering control depends greatly upon the position of the wheels in relation to the rest of the vehicle and the surface over which it travels. Any changes from the specified setting of the wheels affect steering and the riding control of the vehicle. Therefore, the proper wheel alignment is important for vehicle control.

FRONT END GEOMETRY

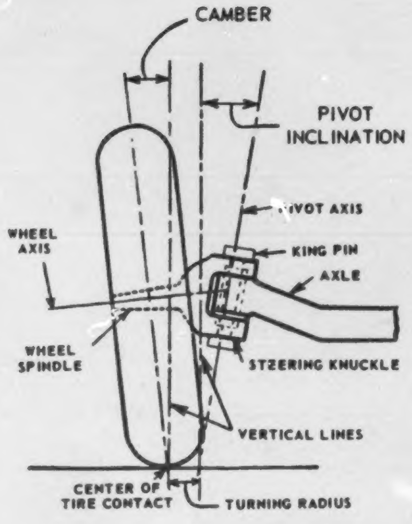
Front end geometry is the term manufacturers use to describe steering and front wheel alignment. Front end geometry includes pivot inclination, wheel caster, wheel camber, toe-in, and toe-out. These terms refer to angles in the front wheel alignment which may change because of driving over rough terrain, striking stationary objects, accident damage, and wear.

Pivot inclination (sometimes called kingpin angle) (fig. 9-7) is the number of degrees that the kingpin is tilted toward the center of the vehicle from a vertical position. Pivot inclination keeps the wheel spindles pointed outward and in line with the axle and helps to make steering easier.


CHECK VALVE
(IN CONTROL
VALVE HOUSING)
PUMP
RESERVOIR
CONTROL
VALVE
POWER
CYLINDER

227.51

Figure 9-6.—Power steering system.

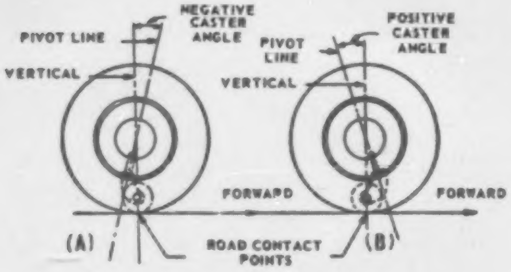

CAMBER
PIVOT
INCLINATION
PIVOT AXIS
KING PIN
AXLE
WHEEL
AXIS
WHEEL
SPINDLE
STEERING KNUCKLE
VERTICAL LINES
CENTER OF
TIRE CONTACT
TURNING RADIUS

81.260

Figure 9-7.—Pivot inclination and camber.

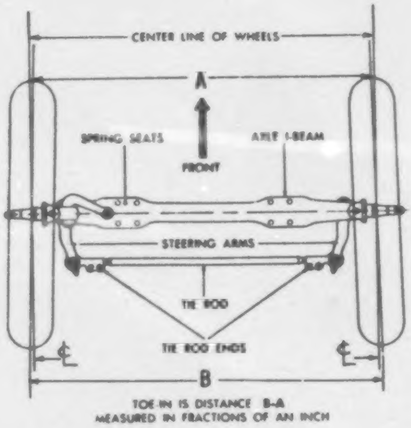
Caster is the number of degrees that the steering knuckle is tilted to the rear, or to the front. Caster tends to keep the front wheels pointed straight ahead and brings them back to straight forward position after a turn. The front wheel of a bicycle is castered and permits the rider to steer without using his hands. When the castered wheel of a bicycle is turned from the straight ahead position by leaning sideways, the front end is slightly raised. After the turn is made, the weight of the bicycle forces the front end down and helps straighten the wheels.

Caster in automotive vehicles with leaf-type springs is obtained by inserting wedges or shims between the front axle and the spring so that the steering knuckle pivots are tilted slightly backward from the vertical. Most modern automotive vehicles do not have leaf-type springs. Vehicles without leaf-type springs use shims between the upper suspension arm and the frame to obtain the desired caster. If the knuckle pivots (kingpins) are tilted forward, the caster is said to be negative. (See fig. 9-8.) The caster is said to be positive when the knuckle pivots are tilted backward. Most vehicles have positive caster, but some modern vehicles have negative caster. Caster is measured in degrees



81.261

Figure 9-8.–(A)Negative caster; (B) positive caster.



81.262

Figure 9-9.–Toe-in.

and varies from approximately 1/2 degree to approximately 3 degrees on modern vehicles.

Camber (fig. 9-7) is the number of degrees that the wheels are tilted in or out at the top. Wheels having camber are closer together at the bottom than they are at the top. Camber, together with pivot inclination, reduces sidethrust on the kingpin bearings in the steering knuckle and support, thus permitting easier steering and less wear of parts. Camber angle, in today's vehicles, very seldom exceeds 1 degree and is obtained by tilting the wheel spindles slightly downward on the steering knuckles. Camber brings the wheels perpendicular to the surface of the road, permitting better rolling contact.

In modern vehicle design, greater pivot inclination reduces the need for excessive camber.

Wheels that have camber must also have toe-in and toe-out. Toe-in (fig. 9-9) is the number of inches that the front wheels point in toward the center of the vehicle. When forced to follow a straight path by motion of the vehicle, cambered wheels tend to slip away from each other. But toe-in wheels tend to travel toward each other and, therefore, balance the effect of camber.

Toe-out is the difference in the turning of the inner wheel, with the outer wheel turned at a 20-degree angle. Tow-out is necessary because of the different turning radius of the front wheels and the necessity of preventing slipping of the front wheels when turning.

STEERING AND ALIGNMENT MAINTENANCE

The driver can sense steering and alignment troubles. He can detect hard steering or play in the steering system. But he will call on the ASM to find the trouble and to remedy it.

Inspection and Testing

Some steering wheel play is normal and provides for easier steering of the vehicle. A large amount of play, however, means a freer movement of the steering wheel without a corresponding movement of the front wheels. Too much wheel play is caused by improper adjustment or wear of the steering linkage, steering knuckle plates, or loose wheel bearings. Worn or improperly adjusted linkage connections can be checked by jacking up the front end of the vehicle, grasping each wheel (front and rear of the wheel), and moving the wheel in and out to check for excessive movement. At the same time, checks for worn steering knuckle parts and loose wheel bearings can be made by grasping the top and bottom of each wheel and shaking to determine the amount of wobble.

Test the steering gear by watching the pitman arm while someone turns the steering wheel one way and then the other. If considerable movement of the steering wheel is required to set the pitman arm in motion, the steering gear is either worn or out of adjustment.

Hard steering may be caused either by very tight adjustments or mechanical difficulties in the steering gear or linkages, not enough air in the tires, or improper wheel alignment.

Sometimes the driver may say that his vehicle "wanders." It may be that he tends to oversteer the vehicle. Nevertheless, the vehicle should be checked for low tire pressures, improper front wheel alignment, and tight or loose wheel and brake adjustments. "Pulling" of the vehicle when braking it could be caused by grabbing brakes. If it "pulls" when driven, check for proper toe-in and toe-out, in addition to the other causes already mentioned.

Steering shocks, caused by sharp and rapid movements of the steering wheel, may be the result of driving over a rough surface or hitting objects on the surface. When the vehicle does not steer properly, it should be checked for sagging springs, defective shock absorbers, or looseness in the steering gear or linkage. Uneven tire inflation also could be the cause.

If the power steering mechanism fails, the steering system will go back to straight mechanical operation. Consult the manufacturer's manual for instructions on repairing power steering units.

If your shop has floating turntables, use them to check steering errors. Run the vehicle up on the tables, then turn the front wheels with steering wheel. Each floating table will turn with the wheel on it and register the angle of the turn. When one wheel turns 20 degrees, the other should turn about 23 degrees.

Before checking front wheel alignment be sure that the front tires are properly inflated, and that steering knuckles and linkages, shock absorbers, and the wheel bearings are correctly adjusted. A number of devices may be used for testing wheel alignment. One of these, the wee-gee board, consists of a metal plate fastened at one end and free to sideswing on the supporting balls. The board measures the sideslip of the tire. When the vehicle is run over the board, watch the indicator as the board moves. If the indicator moves toward the center of the vehicle, the wheels need more toe-in. On the other hand, if the indicator moves away from the center of the vehicle, the wheels have too much toe-in. The wee-gee board is not considered to be very accurate or reliable device for measuring wheel alignment but may be used when none of the more accurate measuring devices is available.

Another device for measuring toe-in is the measuring pole (fig. 9-10). Each pole has a pointer and a gage on one end and can be lengthened and shortened like a curtain rod.

With the vehicle resting on a level floor and the wheels in a straight ahead position, push the vehicle forward a few feet to remove all play in the axle assembly. Put pencil marks on the inside walls of the tires at equal distances from the floor, and at both the front and rear of the tire.

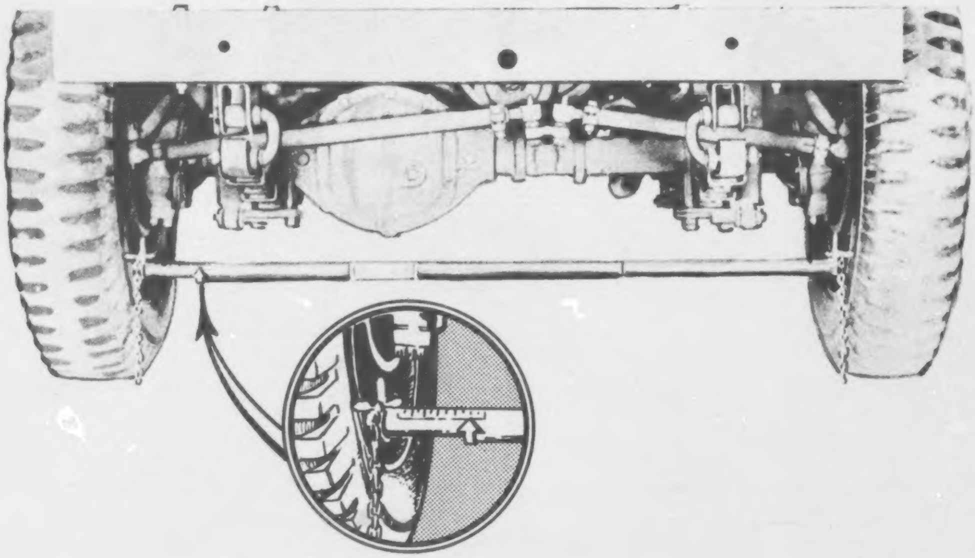
Place the pole between the two marks at the front of the tire and set the pointer at zero. Then, use the pole to measure the distance between the two rear marks. The distance between the two rear marks should conform to the manufacturer's specifications. If not, it is necessary to adjust the toe-in.

Servicing and Adjustments

Adjust the length of the tie-rod to increase or decrease the toe-in. If the vehicle has two tie-rods, it is necessary to adjust each tie-rod equally. In figure 9-10 the right-hand tie-rod is adjusted for the proper setting. Figure 9-11 shows a cross section of one of the ends.

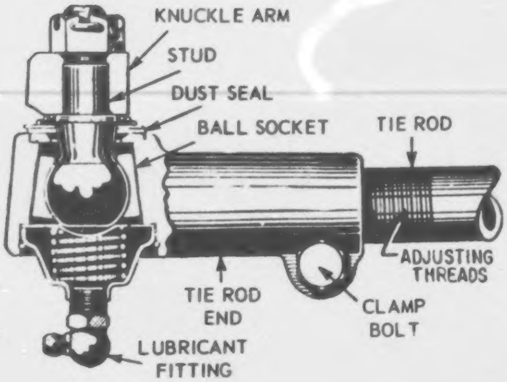
Before making any adjustments, count the number of exposed threads at the ends of the tie-rod. One end of the tie-rod has a right-hand thread and the other a left-hand thread that screws into the fitting. Turning the rod in one direction so that more of these threads enter the fitting will shorten the rod. When you turn the rod in the opposite direction, more threads will be exposed and the rod becomes longer. Very little turning is required to change the length of the rod.

To increase or decrease toe-in, loosen the clamp bolts and turn the rod in the direction which gives you the proper adjustment. Use a pipe wrench and make one turn at a time. Remember, a longer tie-rod will increase toe-in and a shorter tie-rod will decrease toe-in if the



81.263

Figure 9-10.—Measuring pole.



81.264

Figure 9-11.—Tie-rod end showing clamp bolt and adjusting threads.

tie-rod is behind the axle. If the tie-rod is in front of the axle, a longer tie-rod will decrease toe-in, and a shorter tie-rod will increase toe-in. Always tighten the clamp bolts after making an adjustment.

Caster and camber may also be checked with the wee-gee board. If the two front wheels do not register the same reading, the caster and camber of one or both of the wheels are incorrect. On some vehicles caster and camber together are adjusted by turning the upper arm pivot with an Allen wrench (an L-shaped hexagonal bar of tool steel used for setscrews with hexagonal sockets) or a special offset wrench. On other vehicles follow the manufacturer's instructions for correcting caster and camber.

Safety

While repairing or adjusting the steering system and the wheel alignment be sure the vehicle is and will remain stationary. At least one wheel should be blocked on both sides, even if the equipment is on a level surface.

SUSPENSION SYSTEMS

The suspension systems for support equipment differ from most highway driven vehicles. This is because most of the support equipment is not designed to travel over 15 to 20 miles per hour and is only required to move short distances. Most tow tractors have no springs as the axles are bolted to the frame (some tow tractors have only front springs). Most support equipment that have suspension systems have the coil spring type. The components of a suspension system are the springs and shock absorbers.

SPRINGS

Springs support the frame and the body of the vehicle, as well as the equipment mounted on the vehicle. They provide a flexible connection between the wheels and the frame and allow the vehicle to withstand the shocks of uneven surfaces. The best spring would be one that absorbs shock rapidly and returns to its normal position slowly. Since the spring cannot perform this function alone it is assisted by a shock absorber. Very flexible springs allow too much movement of the frame while stiff springs do not allow enough movement.

The springs do not actually support weight of the wheels and axles. These parts make up the unsprung weight of the vehicle, which decreases the action of the springs. Therefore, the unsprung weight is kept to a minimum to permit the springs to support the vehicle frame and load.

Coil springs (fig. 9-12) are used on most independent suspension systems because of low cost and maintenance. The main disadvantage of coil springs is that their frictionless action results in too much pitching of the vehicle. The pitching is dampened by the action of the shock absorber.

Figure 9-13 shows how a coil spring is mounted. The spring seat and hanger are shaped to fit the coil ends and hold the spring in place. Spacers made of rubberized fabric are placed at each end of the coil to prevent squeaking. The rubber bumper, mounted in the spring supporting member, prevents metal to metal contact when the spring is compressed. Coil spring systems require torque rods or a stabilizer shaft to prevent the axle from moving forward and back.

SHOCK ABSORBERS

Springs alone are not always satisfactory in a vehicle suspension system. A stiff spring gives a hard ride because it does not flex and rebound when the vehicle passes over a bump. On the other hand, a spring which is too flexible rebounds too much, and the vehicle rides roughly. To smooth the riding qualities of the vehicle, shock absorbers are used. They prevent excessive jolting of the vehicle by balancing spring stiffness and flexibility. They allow the springs to return to rest slowly after having been compressed. Single acting shock absorbers (fig. 9-14) check the spring rebound; double acting shock absorbers (fig. 9-15) check spring compression as well as rebound. Most shock absorbers used at present are of the double acting type because they permit the use of the more flexible springs.

Most presently used shock absorbers are hydraulically operated. The operation of hydraulic shock absorbers is easy to understand. Liquid hydraulic fluid within the shock absorber is forced through a small opening by a piston when the springs are flexed. Since liquids cannot be compressed, the movement of the piston is controlled by the rate of flow of the hydraulic fluid through the opening. The tube shock absorber, as shown in figure 9-15(B), is used on automotive equipment that does not carry heavy weight. Figures 9-14 and 9-15(A) illustrate shock absorbers for equipment that is designed to carry heavy weight. The tube shock absorber is a self-contained unit that cannot be repaired; it can only be replaced when it becomes inoperative. The heavy duty types can usually be disassembled and repaired.

Shock absorbers are usually attached to the vehicle as shown in figure 9-13. Some shock absorbers are a part of the suspension system as shown in figure 9-12. Rubber mountings are used to fasten shock absorbers to the frame and axle to eliminate wear and noise.

MAINTENANCE

Maintenance of steering and suspension systems includes preoperation and periodic inspections and periodic lubrication.

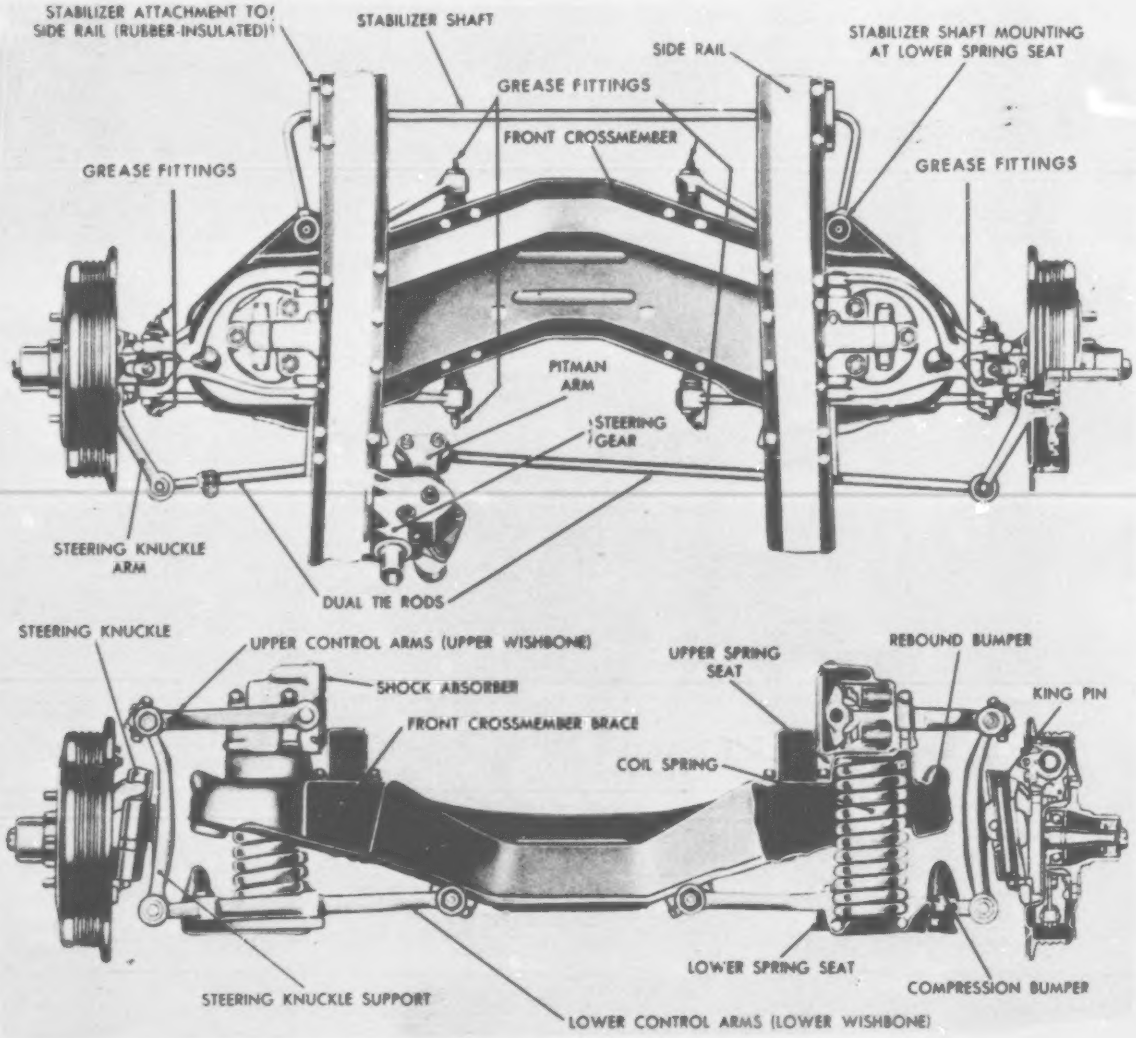
Inspections

Steering components, springs, and shock absorbers should be checked daily, prior to operation of the vehicle. This preoperation inspection consists of a visual inspection for signs of lubricant leakage, corrosion of steering or suspension components, and loose parts such as steering or spring components. Performance of the preoperation inspection is the responsibility of the operator.

Periodic servicing and preventive maintenance includes a detailed visual inspection, as described in the foregoing paragraph. In addition, it includes lubrication.

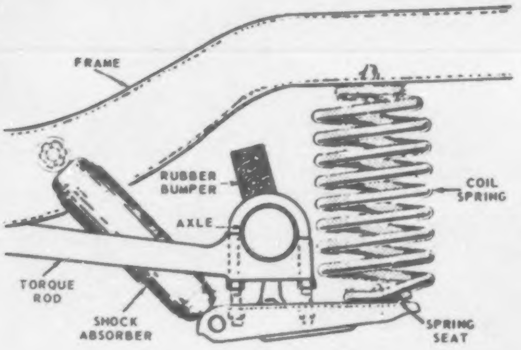
Lubrication

Lubrication involves the greasing and oiling that is performed at the time the entire vehicle is greased. Figure 9-11 shows the tie-rod end grease fitting and figure 9-12 illustrates the same for a coil spring system. Figure 9-3 shows the filler plug for keeping the oil in the steering gear unit to the proper level. Consult the manufacturer's


STABILIZER ATTACHMENT TO SIDE RAIL (RUBBER-INSULATED)
STABILIZER SHAFT
SIDE RAIL
STABILIZER SHAFT MOUNTING AT LOWER SPRING SEAT
GREASE FITTINGS
FRONT CROSSMEMBER
GREASE FITTINGS
GREASE FITTINGS
PITMAN ARM
STEERING GEAR
STEERING KNUCKLE ARM
DUAL TIE RODS
STEERING KNUCKLE
UPPER CONTROL ARMS (UPPER WISHBONE)
SHOCK ABSORBER
FRONT CROSSMEMBER BRACE
UPPER SPRING SEAT
COIL SPRING
REBOUND BUMPER
KING PIN
LOWER SPRING SEAT
COMPRESSION BUMPER
STEERING KNUCKLE SUPPORT
LOWER CONTROL ARMS (LOWER WISHBONE)

227.52

Figure 9-12.—Coil spring suspension.


FRAME
RUBBER BUMPER
AXLE
COIL SPRING
TORQUE ROD
SHOCK ABSORBER
SPRING SEAT

81.242

Figure 9-13.—Coil spring mounting.

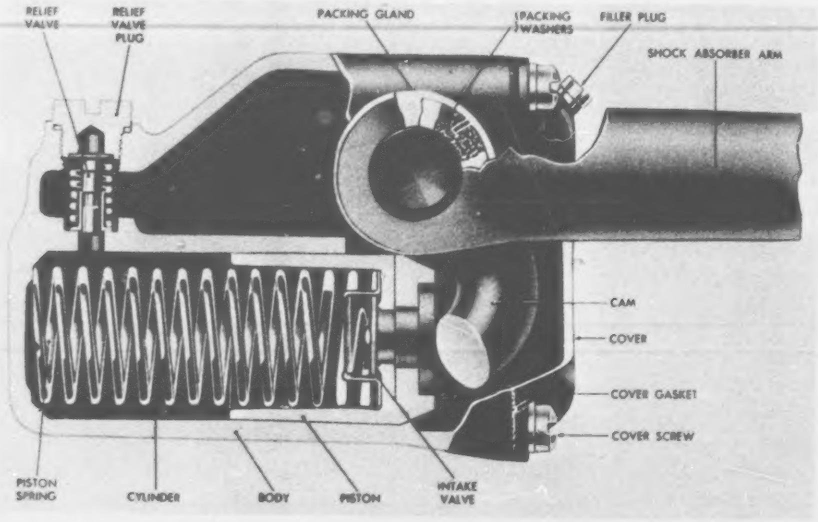
service instructions for the proper lubricant to use.

Frames

The frame is generally constructed of steel and is rigid and strong so that it can withstand the shock, twists, vibrations, and other strains to which it is subjected. The side members or rails are the heaviest parts of the frame. The crossmembers are attached to the side members strongly enough to prevent twisting of the frame. Angular pieces of metal (gusset plates) are riveted or welded at the points where members are joined for added strength.

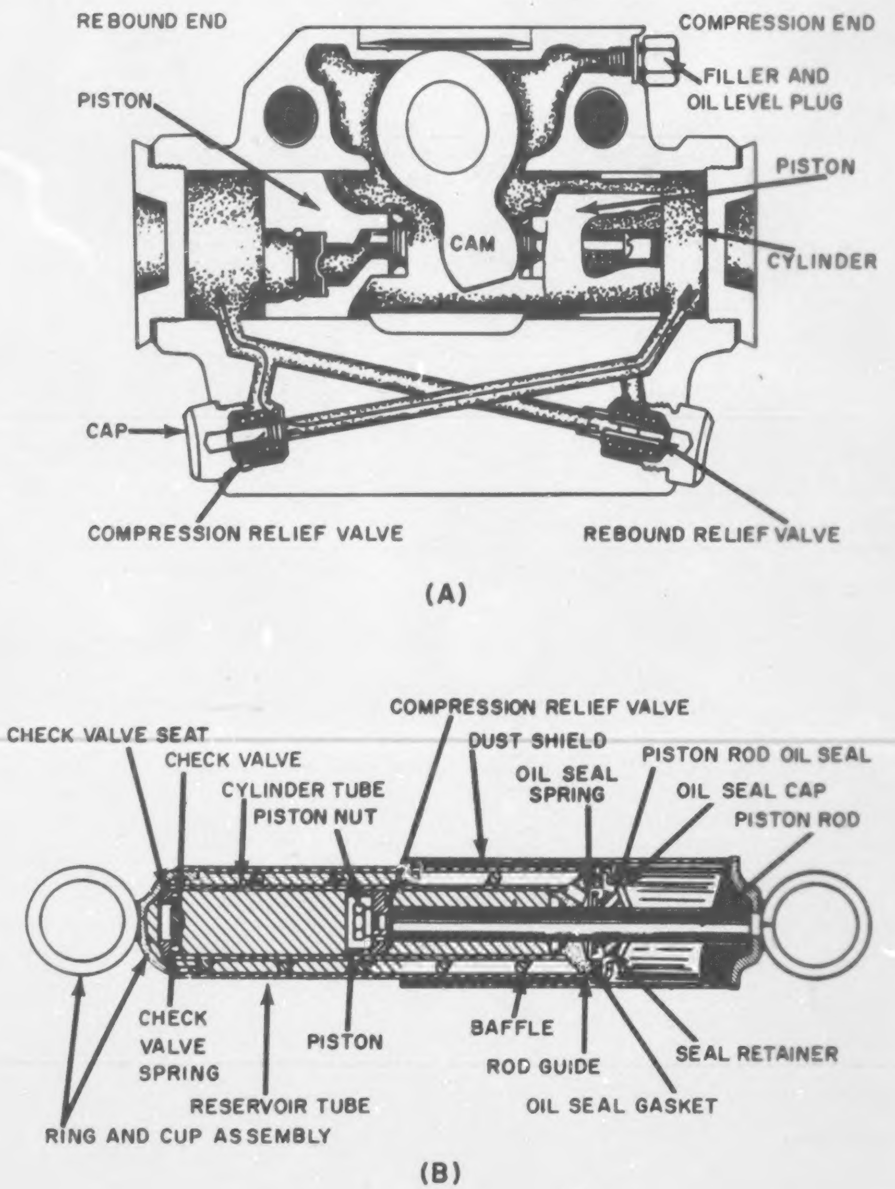
Frames require very little or no maintenance or service. Frames that have been bent, twisted, or broken may be repaired if the damage is not too severe. In order to determine if a frame has been bent, frame alignment can be checked by several methods. One method of checking the frame for forward alignment is by using frame gages. Frame gages, each having a sight mounted on its center crossbar, are hung from the vehicle's frame in three places. Frame alignment is checked by sighting from the front of the vehicle toward the rear. If the sights on the center of the gages do not line up, the frame is out of alignment.

If the frame is out of line it is usually permissible to straighten it, provided that the lack of alignment is not too great. The


RELIEF VALVE
RELIEF VALVE PLUG
PACKING GLAND
PACKING WASHERS
FILLER PLUG
SHOCK ABSORBER ARM
CAM
COVER
COVER GASKET
COVER SCREW
PISTON SPRING
CYLINDER
BODY
PISTON
INTAKE VALVE

227.53

Figure 9-14.—Single action shock absorbers.


REBOUND END
COMPRESSION END
FILLER AND
OIL LEVEL PLUG
PISTON
PISTON
CAM
CYLINDER
CAP
COMPRESSION RELIEF VALVE
REBOUND RELIEF VALVE
(A)
COMPRESSION RELIEF VALVE
CHECK VALVE SEAT
DUST SHIELD
CHECK VALVE
OIL SEAL
SPRING
PISTON ROD OIL SEAL
CYLINDER TUBE
OIL SEAL CAP
PISTON NUT
PISTON ROD
CHECK
VALVE
SPRING
PISTON
BAFFLE
SEAL RETAINER
ROD GUIDE
RESERVOIR TUBE
OIL SEAL GASKET
RING AND CUP ASSEMBLY
(B)

227.54

Figure 9-15.—Double action shock absorbers. (A) Heavy duty type; (B) tube type.

appropriate technical manual must be consulted prior to attempting to straighten the frame. When frame members have been broken or so badly distorted that they require replacement, new members can be installed with either rivets or nuts and bolts. The preferred method is the hot-rivet method, in which the rivet is heated before it is riveted into place. When the front suspension crossmember has been damaged, it is the usual practice to replace it. This is because it is manufactured to such close tolerances that it is practically impossible to restore it to perfect alignment by straightening, if damaged. If the front crossmember is not in line, the front wheels cannot be aligned and poor steering and rapid tire wear will result.

Oxyacetylene Welding

Oxygen unites chemically with acetylene gas in oxyacetylene welding, and when these two gases burn, the flame raises the temperature of the metal so that it will melt and blend together. A welding torch is used to mix the gases in the desired proportions and to direct the flame against the parts to be welded. The melted edges then flow together and after cooling form one solid piece. Welding rods of the same material as the metal being welded are usually added to the weld as it progresses.

The welding equipment is usually fastened on a hand truck (fig. 9-16) and pushed from job to job. It consists of one cylinder containing oxygen and one containing acetylene; acetylene and oxygen pressure regulators complete with pressure gages and connections; a welding torch with mixing head, extra tips, and connections; two lengths of colored hose with adapter connections for the torch and regulators; a special wrench; a pair of welding goggles; a flint lighter; and a fire extinguisher.

OXYGEN.–Oxygen produced for welding purposes is called technical oxygen. Aviator's breathing oxygen which is produced for breathing purposes may also be used for welding. Since technical oxygen must not be used for breathing oxygen, only breathing oxygen is carried aboard aircraft carriers and is used also for welding. Technical oxygen cylinders are solid green and breathing oxygen cylinders are green with a white band around the top.

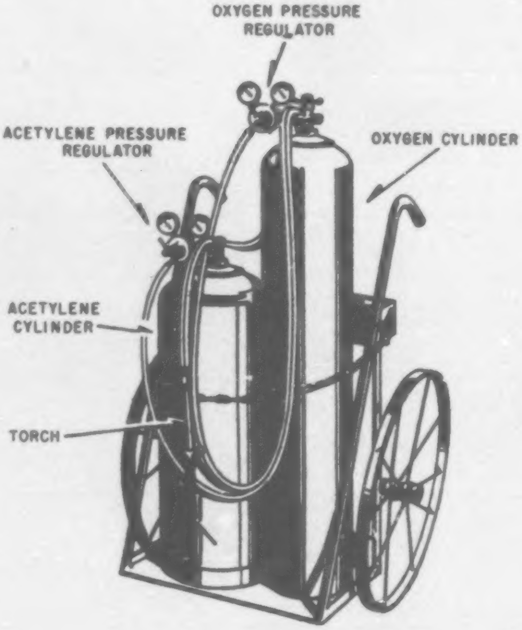


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Figure 9-16.–Oxyacetylene welding outfit.

Each oxygen cylinder has a high-pressure valve located at the top of the cylinder. This valve is protected by a metal safety cap which should always be in place when the cylinder is not in use. Oil and grease become highly combustible when brought in contact with pure oxygen. Oxygen hose and valve fittings should never be oiled or greased or handled with greasy hands. Even greasy spots on clothing may ignite when struck by a stream of oxygen. Beeswax should be used to lubricate oxygen equipment.

ACETYLENE.–Acetylene is a flammable, colorless gas. It has a distinctive, disagreeable odor that is easily detected even when greatly diluted with air. Unlike oxygen, acetylene does not exist free in the air but must be manufactured. When acetylene is mixed with oxygen in the proper proportions and ignited it burns in a blue-white flame, with a temperature of between 5,700° and 6,300°F. The cylinders containing acetylene are painted yellow, and the name of the contents is painted once on each side of the cylinder in black letters running lengthwise. A fully charged acetylene cylinder contains 225 cubic feet of gas at pressure up to 250 psi. These cylinders should not be permitted to become entirely empty or a loss of filler material may result.

The safety precautions for acetylene should be rigidly enforced. Some of the more important ones are as follows:

1. Store acetylene cylinders upright in a protected, ventilated, dry place away from heat and combustible material.
2. Use the gas only through pressure-reducing regulators that reduce the pressure to below 15 psi.
3. Use the T-wrench to open the acetylene valve slowly and leave the wrench in place on the valve so the valve may be closed quickly.
4. Keep flame and heat away from the cylinders and avoid damaging valves or fuse plugs since this could cause leaking. Test for leaks with soapy water, not open flame.
5. Have the outlet pointed away from the oxygen cylinder. Open the cylinder valve momentarily before attaching the regulator to blow away dirt.
6. Do not interchange equipment intended for acetylene with that intended for oxygen, and keep the valves closed on empty cylinders.

Should an acetylene cylinder catch fire use a wet blanket to extinguish it. If this fails, spray the cylinder with water to keep it cool.

PRESSURE REGULATORS.–Acetylene and oxygen regulators reduce pressures and control the flow of gases from the cylinder to the torch. The outlet fitting on acetylene regulators has left-hand threads to prevent the interchange with oxygen hose which has right-hand threads. In a portable welding unit each regulator is equipped with two pressure gages. One is a high-pressure gage that indicates the cylinder pressure, and the other is a low-pressure gage that indicates the pressure in the hose leading to the torch (working pressure).

Before opening the valve on a cylinder, the adjusting screw on the regulator should be fully released by turning to the left. This closes the valve inside the regulator and protects the mechanism against damage. A two-stage regulator is usually used with portable welding units. In two-stage regulators the pressure reduction is accomplished in two separate steps. The two independent diaphragms and valve assemblies make the operation extremely efficient.

WELDING TORCH.–The welding torch is the unit that mixes the oxygen and acetylene in the proper proportions and controls the volume of the gases and the direction of the flame. The torch has two needle valves for adjusting the flow of each of the gases. A handle, two tubes, a mixing head, and a tip are also provided. Tips are interchangeable and come in various styles and sizes for welding different thicknesses of metal. The most widely used torch, the balanced-pressure type, has the oxygen and the acetylene both fed to the torch at the same pressure. The openings to the mixing chamber for each gas are equal in size, and the delivery of each gas is independently controlled.

The torch tip delivers and controls the final flow of gases. It is important that the correct tip be used with the proper gas pressures to ensure the job is satisfactorily welded. The nature of the weld, the material, the experience of the welder, and the position in which the weld is made all determine the correct size of the tip opening. The size of the tip opening determines the amount of heat (not the temperature) applied to the work. If the tip is too small, the heat provided will be insufficient to produce penetration to the proper depth. If the tip is too large, the heat will be too great and holes will be burned in the metal. The hoses used in connecting the cylinders to the torch must be specially made for the purpose. Oxygen hose is either green or black and acetylene is red or maroon.

A flint lighter is provided for ignition of the torch. The lighter consists of a file-like piece of steel and a piece of flint that can be drawn across the steel. These are mounted in a wire spring device that assumes an open position after being squeezed to produce the spark. CAUTION: Do not use matches to light the torch. They cause the hand to be too close to the torch and could cause severe burns to the hand.

Welding goggles are fitted with colored filter lenses to prevent harmful ultraviolet rays from entering the eyes. They also keep out heat, sparks, and molten metal. The filter lenses should be protected by a clear glass cover. The desired lenses are those having the darkest possible shade, consistent with the ability to show a clear definition of the work without eyestrain. Goggles should fit closely and should be worn at all times during welding and cutting operations. Special goggles are available to be worn with spectacles.

The material in the welding or filler rod not only adds reinforcement to the weld area but also adds desired properties to the finished weld. By selecting the proper type of rod, either tensile strength or ductility can be secured in a weld, or both may be secured to a reasonably high degree. Welding rods are manufactured in standard 36-inch lengths and in diameters from 1/16 inch to 3/8 inch. The diameter of the rod used is governed by the thickness of the metals being welded. If the rod is too small, it will not conduct heat away from the weld fast enough and a burned weld will result. A rod that is too large will chill the weld.

The neutral flame used in welding does not alter the composition of the metal being welded and therefore is best suited for most welding. The neutral flame burns at approximately 5,850° F. A balanced mixture of one part oxygen and one part acetylene is supplied from the torch when the flame is adjusted to neutral. The neutral flame is divided into two distinct zones. The inner zone consists of the cone–a white, clearly defined, round, smooth cone, 1/16 to 3/4 inch in length. The outer zone, made up of completely burned oxygen and acetylene, is blue with a purple tinge at the point and edges. A neutral flame melts the metal without changing its properties and leaves the metal clear and clean. If the mixture of oxygen and acetylene is correct, the neutral flame allows the molten metal to flow smoothly and few sparks are produced when welding most metals.

To adjust the flame, prepare to light the torch by opening the torch acetylene valve 1/4 to 1/2 turn. Light the torch. The flame will be yellow in color and give off smoke and soot. Next open the oxygen valve slowly. The flame will gradually change in color from yellow to blue and will show characteristics of excess acetylene flame. The excess acetylene flame includes a bluish-white inner cone, a white intermediate cone, and a light blue outer flame. It will also have a feather at the tip of the inner cone. Now close the acetylene valve very slowly. The intermediate cone will get smaller until it finally disappears completely. The point of complete disappearance of the intermediate cone is the point at which the neutral flame is formed. To utilize the complete welding capability of the torch, the oxygen and acetylene valves should be almost completely open.

Hold the torch so that the tip is in line with the joint to be welded and inclined between 30 and 60 degrees from the perpendicular. The exact angle depends on the type of weld to be made, the amount of preheating necessary, and the thickness and type of metal. The thicker the metal, the more nearly vertical the torch must be for proper penetration. The white cone of the flame should be held about 1/8 inch from the surface of the weld. If the torch is held in the correct position, a small puddle of molten metal will form. The puddle will be composed of equal parts of the two pieces being welded. After the puddle appears, begin a movement of the tip in a semicircular or circular motion. This movement assures an even distribution of heat to both pieces of metal. A filler rod is used to add strength and reinforcement to the weld. Welding is always done in the flat position if possible. The puddle is much easier to control and the welder can work longer without tiring.

CUTTING.–Cutting iron or steel with an oxyacetylene torch simply speeds up the process of oxidation of the metal in a localized area because iron oxidizes more readily when hot. Pure oxygen, when directed on a hot piece of iron, increases the rate of oxidation so much that the metal is actually burned away. The metal is heated to a bright red, which indicates that the kindling or ignition temperature has been reached, and a jet of high-pressure oxygen is directed against it. This oxygen blast combines with the hot metal and forms an intensely hot oxide. The molten oxide is blown down the sides of the cut, heating the metal in its path to a kindling temperature. The metal thus heated also burns to an oxide which is blown away on the underside of the piece.

A cutting torch (fig. 9-17) combines a heating flame with a jet of pure oxygen under pressure. The heating flame preheats the metal to a bright red, and the oxygen jet is directed upon the hot metal to burn it away and thus form a slit, known as a kerf, in the metal. The heating flame in a cutting tip is usually not fed by a single hole as in a welding tip but comes through several holes which are arranged in a ring around a larger center hole for oxygen. The center tube tapers as it reaches the tip opening to increase the velocity of the oxygen. The high-pressure oxygen cutting jet is regulated by an auxiliary oxygen control valve operated by a lever as shown in figure 9-17. In cutting as in welding, the pressure of oxygen and acetylene and the size of the tip are determined by the thickness and quality of the metal to be cut.

The line to be cut should be marked on the metal with soapstone or chalk. Then place the metal so that this line is beyond the end of the welding bench. If an exceptionally straight cut is desired, clamp a bar of steel across the material to guide the torch. Hold the torch in the right hand so that there is instant and positive control of the oxygen control lever. The left hand should be used to steady and guide the cutting torch. A fire brick or some other similar object placed on top of the material to be cut will provide a good rest for the left hand and help steady the torch. If the cutting tip wavers from side to side, a wide kerf will be made and will result in slower speed and greater oxygen consumption.

Begin cutting at the edge of the piece. Hold the tip perpendicular to the surface of the metal, keeping the inner cone about 1/16 inch from the line. Hold the flame at this point until a spot in the metal turns bright red, then gradually depress the oxygen control lever. As soon as the cutting starts there will be a shower of sparks from the lower side of the material, and the oxygen control lever should then be fully depressed. When the cut has been started all the way through the material, move the torch slowly but steadily along the line. The motion of the cutting torch should be just fast enough to penetrate completely without excessive oxidation or melting.

Some of the most important safety regulations for using the oxyacetylene welding/cutting equipment are as follows:

1. Do not use oil, grease, or any lubricant on welding or cutting equipment. Never permit oil or grease to come in contact with oxygen under pressure.

2. Always use the proper tip or nozzle and operate it at the proper pressure for the work

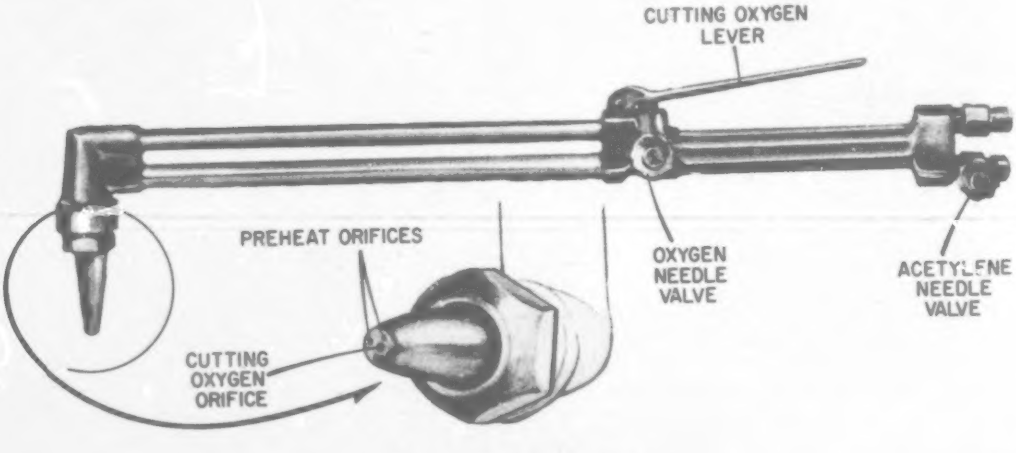

Figure 9-17.–Cutting torch. 227.56

involved. This information should be taken from the tables furnished with the equipment.

3. Do not experiment or change regulators in any way. Always use regulators with the gas for which they were designed.

4. Use friction lighters, not matches, to light torches to prevent possibility of serious hand injury. Do not light torches from hot metal.

5. Do not permit a mixture of unburned oxygen and acetylene to accumulate in a confined space. This accumulation can become an explosive mixture and cause damage and personal injury when accidentally ignited. Welding should always be done in a well ventilated space.

6. Always wear goggles designed for welding use when working with a lighted torch.

7. When extinguishing the torch, close the acetylene valve first and then the oxygen valve.

Practice and experience will make you a good welder. When learning to weld be sure an experienced welder is your instructor and is on hand each time you are using the torch. Plan your work so you always know what you will attempt to accomplish next.

For further information on welding, the ASM should consult *Aviation Support Equipment H 3&2,* NAVEDTRA 10316-A, chapter 7.

CHAPTER 10

POWER TRAINS

The aviation support equipment that is powered and mobile must have a method of transferring the power from the engine to the wheels. This is the power train and consists of clutch, transmission, propeller shaft and universal joints, differential, and axles. Figure 10-1 shows one type of power train.

This chapter contains a general discussion of these parts of a power train. The operation and repair manuals which accompany each piece of equipment will give more detailed information.

CLUTCH ASSEMBLIES

The clutch is placed in the power train of motorized equipment for two purposes:

First, it provides a means of disconnecting the power of the engine from the driving wheels and accessory equipment. When the clutch is disengaged, the engine can run without driving the vehicle or operating the accessories.

Second, when the vehicle is started, the clutch allows the engine to take up the load of driving the vehicle or operating accessories gradually and without shock.

Clutches are located in the power train between the source of power and the operating unit. Usually, they are placed between the engine and the transmission assembly, as shown in figure 10-1.

Clutches transmit power from the clutch driving member to the driven member by friction. In the PLATE CLUTCH (fig. 10-2), the

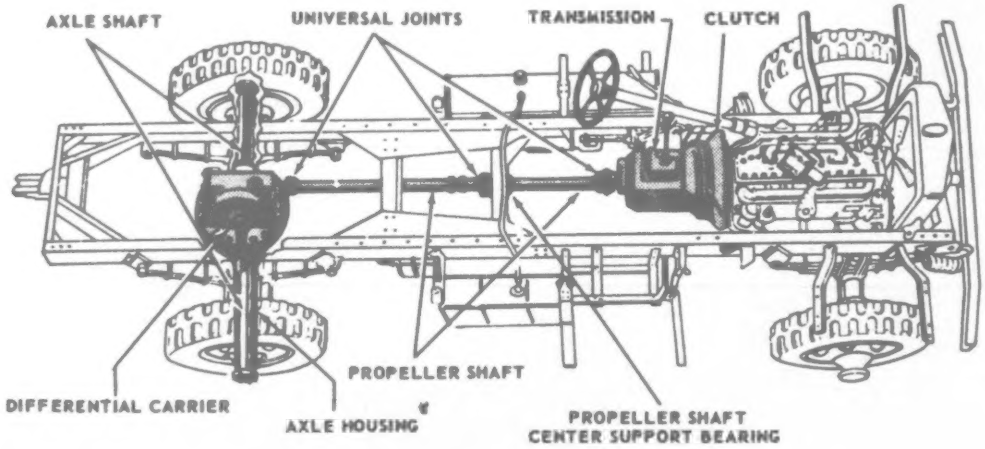

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Figure 10-1.—Power train.

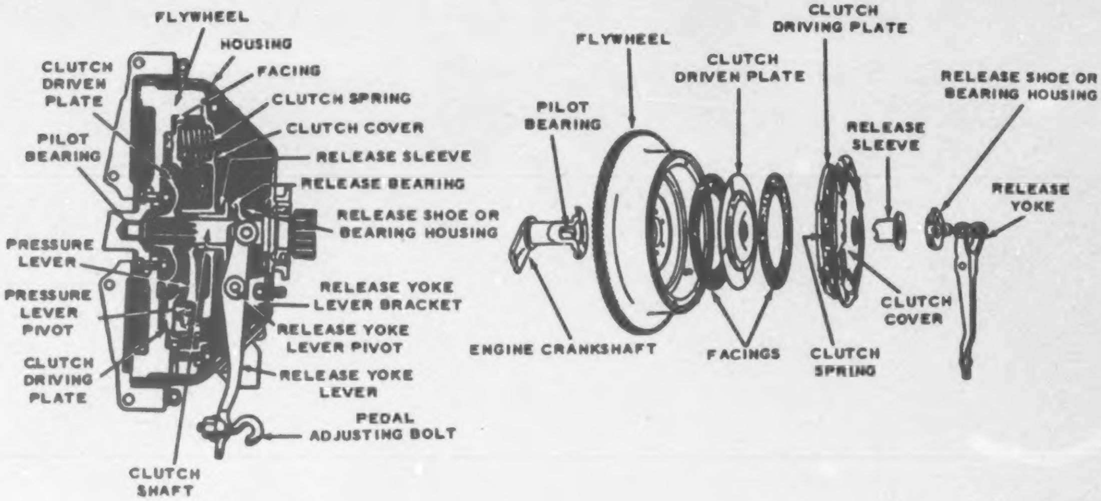
FLYWHEEL
HOUSING
CLUTCH DRIVEN PLATE
FACING
CLUTCH SPRING
PILOT BEARING
CLUTCH COVER
RELEASE SLEEVE
RELEASE BEARING
RELEASE SHOE OR BEARING HOUSING
PRESSURE LEVER
PRESSURE LEVER PIVOT
RELEASE YOKE LEVER BRACKET
RELEASE YOKE LEVER PIVOT
CLUTCH DRIVING PLATE
RELEASE YOKE LEVER
PEDAL ADJUSTING BOLT
CLUTCH SHAFT
CLUTCH DRIVING PLATE
FLYWHEEL
CLUTCH DRIVEN PLATE
RELEASE SHOE OR BEARING HOUSING
PILOT BEARING
RELEASE SLEEVE
RELEASE YOKE
CLUTCH COVER
ENGINE CRANKSHAFT
FACINGS
CLUTCH SPRING

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Figure 10-2.—Exploded and cross-sectional view of a plate clutch.

driving member or plate, which is secured to the engine flywheel, is gradually brought in contact with the driven member (disc). The contact is made and held by strong spring pressure controlled by the driver with the clutch pedal. With only a light spring pressure, there is little friction between the two members, and the clutch is permitted to slip. As the spring pressure increases, friction also increases, and less slippage occurs.

When the driver removes his foot from the clutch pedal and full spring pressure is applied, the speed of the driving plate and driven disc is the same, and all slipping stops. There is then a direct connection between the driving and driven shafts.

In most clutches, there is a direct mechanical linkage between the clutch pedal and the clutch release yoke lever. On many late model vehicles, and on some of the larger units which require great pressure to release the spring, a hydraulic clutch release system is used. A master cylinder, similar to the brake master cylinder, is attached to the clutch pedal. A cylinder, similar to a single-acting brake wheel cylinder, is connected to the master cylinder by flexible pressure hose or metal tubing. The slave cylinder is connected to the clutch release yoke lever. Movement of the clutch pedal actuates the clutch master cylinder. This movement is transferred by hydraulic pressure to the slave cylinder, which in turn actuates the clutch release yoke lever.

CLUTCH FACINGS

Clutch facings (fig. 10-3) are the linings attached to clutch-driven members. They will wear if the clutch slips. When the driver rides the clutch to rest his foot, he is causing the clutch facings to slip a little and thus requiring the ASM to adjust clutch linkages for clutch facing wear and to replace the facings when they are worn excessively.

When badly worn, the driven member of a clutch (a steel disc and linings) is usually replaced as a unit in passenger cars and small trucks. Linings in some clutches are removed from the disc by pin punching the rivets on the riveted side. It is often easier to remove these linings by spot drilling the rivets with a drill and then punching them out. The new linings are fastened to the disc at the same time; that is, you must place the front and rear linings to each side of the steel clutch disc and place the rivets

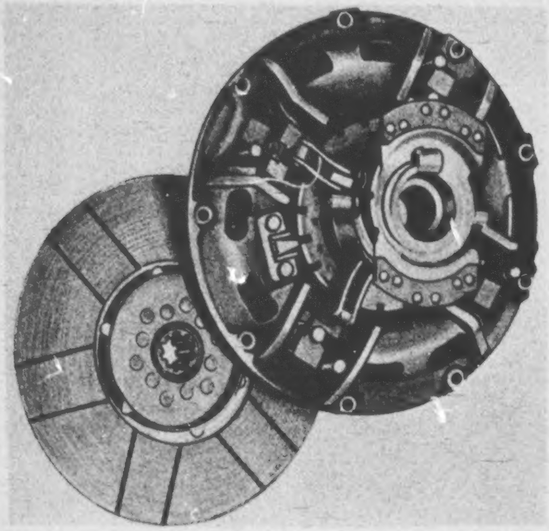

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Figure 10-3.—Clutch facings of asbestos fiber interwoven with brass wire.

through both linings and disc simultaneously; half of the rivets installed through the front lining and the other half through the rear lining. Handle the unit carefully while replacing the linings to prevent distortion, and to keep it clean. A distorted driven member will prevent proper clutch adjustment, and oil or grease on the facing will cause the clutch to slip.

TYPES OF CLUTCHES

There are various types of clutches. The type most used in light automotive aviation support equipment is the previously mentioned plate clutch. The plate clutch is a simple clutch with two plates, and one disc which is clamped between the two plates. Exploded and cross-sectional views of a plate clutch are shown in figure 10-2.

Single Disc Clutch

The driving members of the single disc clutch consist of the flywheel and the driving (pressure) plate. The driven member consists of a single disc, splined to the clutch shaft and faced on both sides with friction material. When the clutch is fully engaged, the driven disc is firmly clamped between the flywheel and the driving plate by pressure of the clutch springs, forming a direct, nonslipping connection between the driving and driven members of the clutch. In this position, the driven disc rotates the clutch shaft to which it is splined. The clutch shaft is connected to the driving wheels through the transmission, propeller shaft, final drive, differential, and axles.

The double disc clutch (fig. 10-4) is substantially the same as the single disc clutch except that another driven disc and intermediate driving plate is added.

CLUTCH PEDAL ADJUSTMENT

Clutch pedal adjustments are made to take up wear of the clutch facings and wear in the linkage between the clutch pedal and the clutch throwout lever. Most clutches have adjusting devices similar to those illustrated in figure 10-5.

The screw adjustment in the tie-rod between the pedal and throwout lever, however, must be adjusted periodically to compensate for normal wear of clutch disc facing. After loosening the locking nut and unfastening one end of the tie-rod, the length of the rod can be increased or decreased by turning the loose end. The length of the rod must be adjusted to allow 1/2-inch to 1 1/2-inch free movement of the clutch pedal, depending upon manufacturers' specifications. (See fig. 10-5.) You can feel the point where the free movement ends and the clutch begins to release by the increased foot pressure required to depress the pedal. If you leave the clutch pedal with too little free movement, it will cause the throw-out bearing to ride on the pressure plate fingers, which will result in clutch slippage and damage to the pressure plate, the facings, and throw-out bearing. Too much free movement (free travel) may keep the clutch from completely disengaging, thereby making it impossible to shift the transmission with the engine running. After you make the adjustment, be sure to tighten the locknut, and lock the clevis pin position with a new cotter pin.

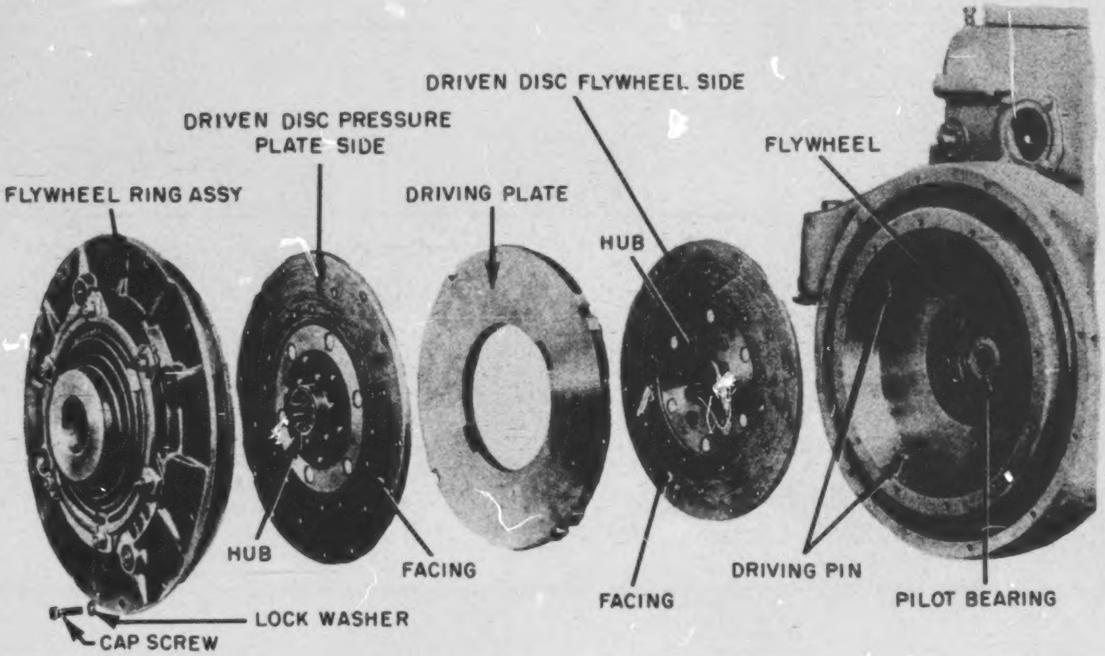

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Figure 10-4.—Double disc clutch-exploded view.

You will find other linkage arrangements and devices for clutch-pedal adjustment. They are not difficult to understand, and with a little practice, you will have no trouble making these adjustments, always check with manufacturers' specifications.

CLUTCH TROUBLESHOOTING

The information given in this section is general and can be applied to nearly every type of clutch that you are likely to encounter. You will probably have special problems for which the solution can be found only by referring to the manufacturer's manual.

Several types of clutch trouble may be encountered. Usually the trouble is fairly obvious. When the malfunction is explained on a discrepancy report, a quick personal check of the vehicle will generally enable you to correctly diagnose the trouble. It is your responsibility to see that the job is properly performed with a minimum of work. Clutch trouble generally falls into one of six categories:

1. Slipping.
2. Chattering or grabbing when engaging.
3. Spinning or dragging when disengaging.
4. Clutch noises.
5. Clutch pedal pulsations.
6. Rapid disc facing wear.

Slipping Clutches

A clutch that slips when it is engaged is extremely hard on the clutch facings. The facings will wear and burn so badly that the clutch may soon become completely inoperative. Heat from a slipping clutch can soon become great enough to warp the pressure plate and to cause heat checks (small surface cracks) on both the flywheel and pressure plate.

Clutch slippage is particularly noticeable during acceleration, especially from a standing start or in low gear. You can test for clutch

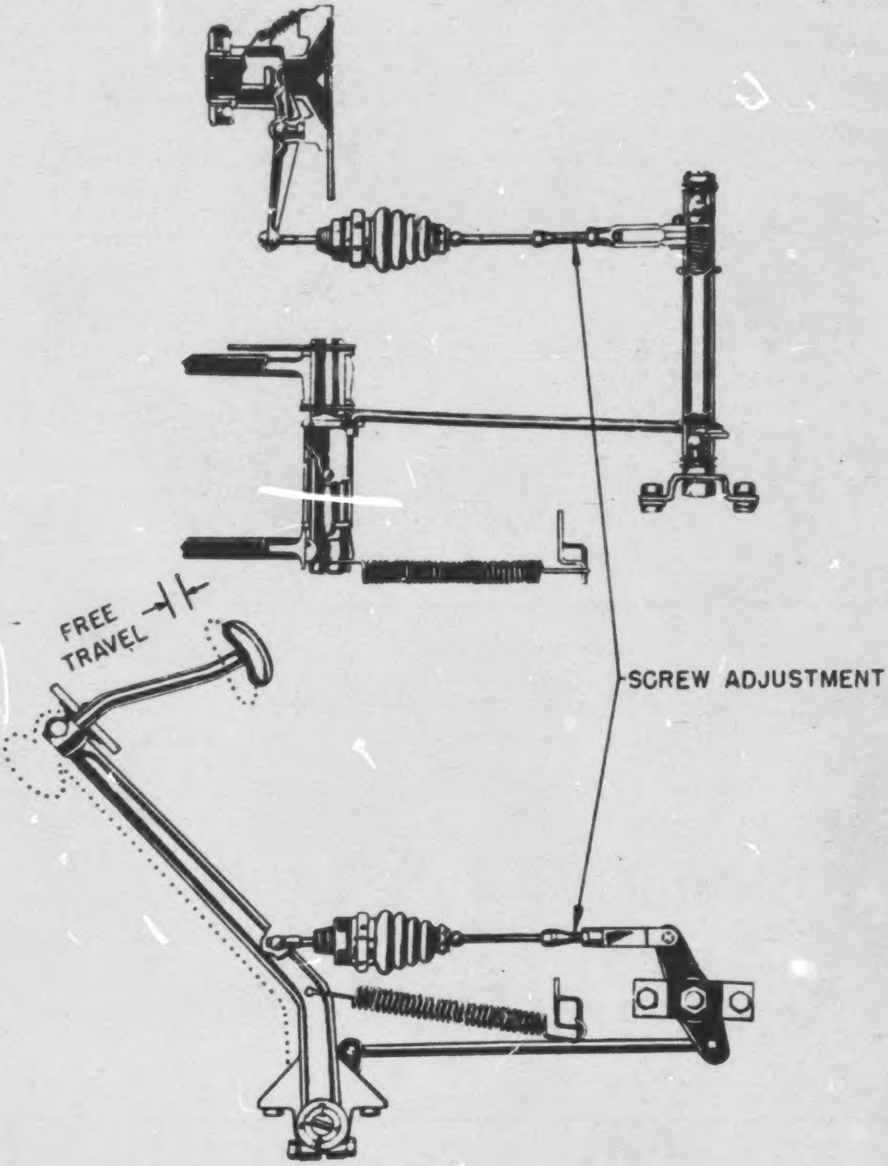

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Figure 10-5.–Clutch linkage.

slippage by starting the vehicle engine, setting the handbrake, and slowly releasing the clutch pedal while accelerating the engine. If the clutch is in good condition, the engine should stall immediately when the clutch engagement is completed.

There are several conditions that can cause clutch slippage. For instance, the clutch linkage may not be properly adjusted. With an incorrect adjustment that reduces the pedal lash too much, the throwout (release) bearing will press against the release levers even with a fully released clutch pedal. This prevents full pressure plate engagement. Therefore, it will not exert sufficient pressure to hold the friction disc tightly enough against the flywheel. As a result, there is slippage between the surfaces. The way to correct this is to adjust the clutch linkage to give specified clutch pedal lash (free travel).

If the clutch release linkage binds, it may keep the clutch from returning to the fully engaged position. This will, of course, cause the clutch to slip. This binding can generally be eliminated by proper lubrication of all points of friction in the linkage. It may be necessary to readjust and realign the clutch operating linkage. If readjustment, lubricating, and freeing of the clutch linkage does not correct the trouble, it may be necessary to remove the clutch for repair. Any of the following conditions within the clutch itself could cause slippage:

1. Weak or broken pressure springs.
2. Worn friction disc facings.
3. Grease or oil on the disc facings.

Replacing the facings or the completed disc is necessary to remedy condition 2 or 3 listed above.

Clutches That Chatter or Grab When Engaging

There are several things that will cause a clutch to chatter or grab when it is being engaged. Loose spring shackles or U-bolts, loose transmission mounting, and worn engine mounts are among the items that must be checked. If the clutch linkage binds, it may release suddenly to throw the clutch into quick engagement, with a resulting heavy jerk. If all these items are checked and found to be in good condition, then the trouble is inside the clutch itself and the clutch will have to be removed from the vehicle for repairs.

In the clutch, the trouble could be due to oil or grease on the disc facings or to glazed or loose facings. Binding of the friction disc hub on the clutch shaft could prevent smooth engagement; this condition will require cleaning of the splines in the disc hub and on the clutch shaft. Broken parts in the clutch, such as broken disc facings, broken cushion springs in the disc, or a broken pressure plate could cause poor clutch action or grabbing.

Clutches That Spin or Drag When Disengaged

The clutch friction disc may spin briefly after the clutch is disengaged. In other words, it takes a moment for the friction disc to come to rest. This normal spinning should not be confused with a dragging clutch. When the clutch drags, the friction disc continues to rotate with and to rub against the flywheel or pressure plate.

When this condition exists the first thing to check is the pedal-linkage adjustment. If there is excessive free travel of the clutch pedal, even full movement of the pedal will fail to force the release bearing in far enough against the release levers to release the clutch fully. If adjustment of the linkage does not correct the trouble, the trouble is in the clutch and the clutch must be removed, disassembled, and repaired.

When the trouble is in the clutch assembly, you will generally find a warped disc or pressure plate, or the facing on the disc may be loose. On the type of pressure plate assembly with adjustable release levers, improper adjustment of the levers could prevent full disengagement so that the clutch would drag. A friction disc hub that is binding on the clutch shaft can also cause the clutch to drag.

Clutch Noises

When an operator reports that a clutch is making noise, find out whether the noise is heard when the clutch is engaged or when it is disengaged. Clutch noises are usually most noticeable when the engine is idling and the clutch disengaged.

A disc hub that is loose on the clutch shaft will make a noise when the clutch is engaged. This would require replacement of the disc or clutch shaft or perhaps both if both are worn excessively. Friction disc dampener springs that are weak or worn will also cause clutch noises. If the engine and transmission are not properly aligned, the disc hub will move back and forth on the clutch shaft. This will cause the splines of the disc hub and clutch shaft to wear; thus, a noisy clutch will soon appear. Any time excessive wear is found on the splines of the disc hub and/or the clutch shaft, always check the transmission and engine alignment.

If clutch noises are noticeable when the clutch is disengaged, the trouble will likely be in the clutch release bearing. The bearing is probably worn, binding, or has lost its lubricant. Most clutch release bearings are factory lubricated. As a rule, when the release bearing starts making a noise, it must be replaced. If the release levers on the pressure plate assembly are not properly adjusted they could rub against the disc hub when the clutch is disengaged. If the pilot bearing in the crankshaft is worn or lacks lubricant, it will sometimes produce a high-pitched whine when the transmission is in gear, the clutch is disengaged, and the vehicle is standing still. Under these conditions, the clutch shaft, which is piloted in the bearing in the crankshaft, is stationary, but the crankshaft and bearing are turning.

Clutch Pedal Pulsation

A series of slight movements that can be felt on the clutch pedal or operating lever when the clutch is being disengaged is called clutch pedal pulsation. These pulsations are noticeable when a slight pressure is applied to the clutch pedal. This is an indication of trouble that could result in serious damage if not corrected immediately. There are several conditions that could exist that would cause these pulsations. One possible cause is misalignment of the engine and transmission.

If the engine and transmission are not in line, detach the transmission and remove the clutch assembly. Check the clutch housing alignment with the engine and crankshaft. At the same time, the flywheel can be checked for wobble since a bent crankshaft flange, or a flywheel that is not seated on the crankshaft flange, will produce clutch pedal pulsations. If the flywheel does not seat on the crankshaft flange, remove the flywheel; after cleaning the flange and the flywheel, replace the flywheel making sure a positive seat is obtained between the flywheel and crankshaft flange. If the flange is bent at the crankshaft, the crankshaft must be replaced.

Other causes of clutch pedal pulsations include uneven release-lever adjustments, warped pressure plate or warped clutch disc. If the pressure plate or clutch disc is warped, it should be replaced.

Rapid Clutch Disc Wear

Rapid clutch disc wear will be caused by any condition that permits slippage between the clutch disc facings and the flywheel or pressure plate. An operator may have the habit of "riding" the clutch; this practice can cause slippage. Frequent use of the clutch or slow releasing of the clutch after disengaging will increase clutch facing wear. The remedy here, is for the operator to use the clutch properly and only when necessary. Broken or weak pressure springs within the plate assembly will cause slippage The springs must be replaced to correct this problem. Improper clutch linkage adjustment or binding of the linkage may prevent full spring pressure from being applied to the clutch disc. Any condition that keeps less than full spring pressure from being applied to the clutch disc is apt to cause slipping.

CLUTCH LUBRICATION

Some clutches require lubrication, and others do not. Check with the manufacturer's instruction manual for instructions on the lubrication of the clutch throwout bearing. The clutch pedal control shaft and linkages, however, are usually equipped with high pressure fittings which should be greased with chassis lubricant at periodic intervals.

TRANSMISSIONS

A speed and power changing device is needed between the engine of an automobile and the driving wheels in order to meet the speed and power requirements of the vehicle. To keep the engine as small as possible and still permit it to set the vehicle in motion, which requires more power than keeping it in motion, a transmission is used. Besides providing the power needed to start the vehicle moving, the transmission permits intermediate applications of power up to the top speed of the vehicle. Gears and a shifting mechanism in the transmission are used to obtain the desired power application.

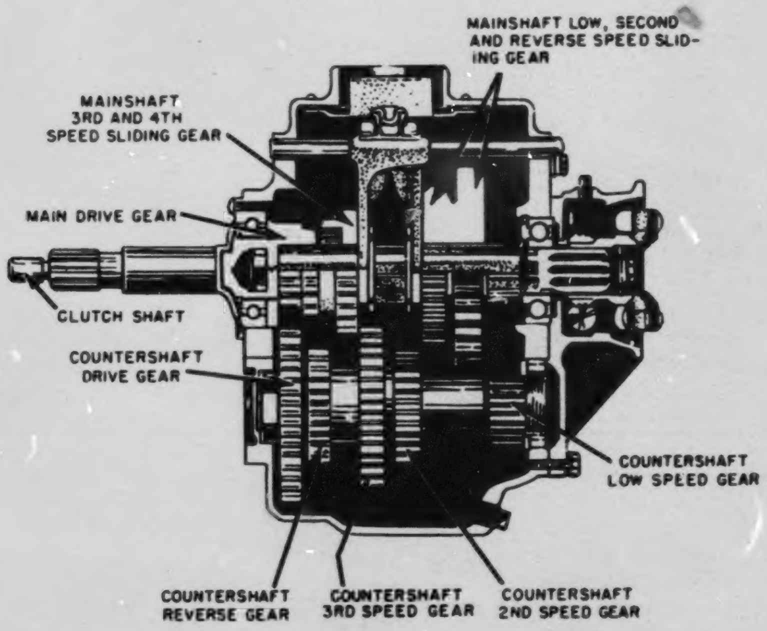
STANDARD TRANSMISSION

The transmission (fig. 10-6) is part of the power train. It is located on the rear of the engine between the clutch housing and the propeller shaft, as shown in figure 10-1. The transmission transfers engine power from the clutch shaft to the propeller shaft and allows the driver or operator to control the power and speed of the vehicle. The transmission shown in figures 10-6 and 10-7 is a sliding gear transmission. Many late model vehicles have either constant mesh or synchromesh transmissions (explained later). However, the principles of operation are the same.

Chapter 6 of the Rate Training Manual, *Basic Machines,* NavPers 10624-A, discusses gears and their mechanical advantages, and explains how to compute the speed and reduction ratio of gears in a typical automotive transmission. If you need review on this point, study chapter 6 of *Basic Machines.* This manual will help you to understand the transmission and power transfer mechanisms described in this chapter.

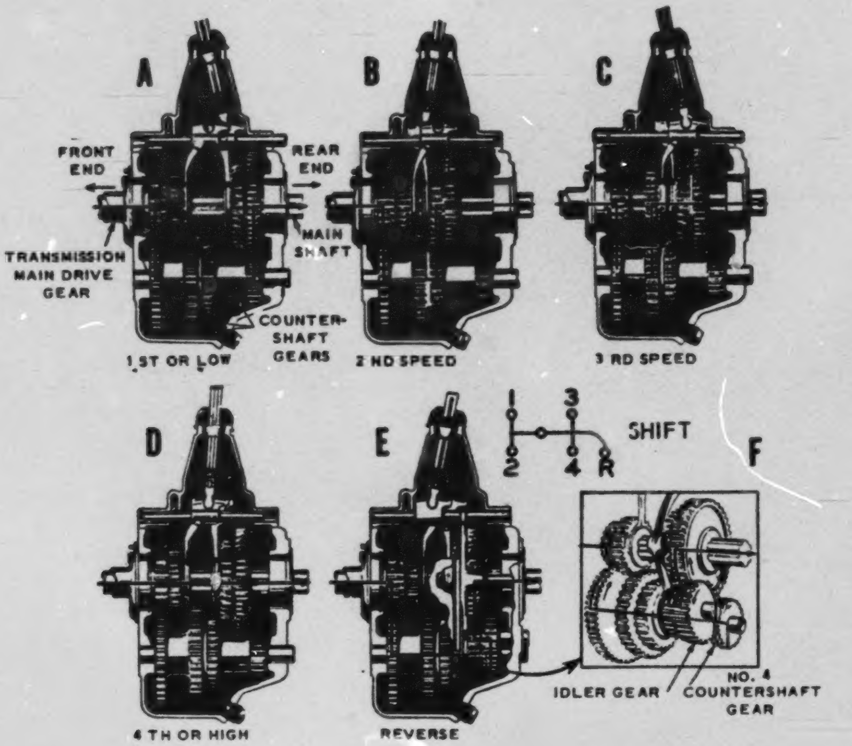
FOUR-SPEED TRANSMISSION

The gear shift lever positions shown in the small inset in figure 10-7 are typical of most four-speed transmissions. The gear shift lever, shown at A, B, C, D, and E in the illustration, moves the position of the two shifting forks which slide on separate shafts secured in the transmission case cover. Follow the separate


MAINSHAFT LOW, SECOND AND REVERSE SPEED SLIDING GEAR
MAINSHAFT 3RD AND 4TH SPEED SLIDING GEAR
MAIN DRIVE GEAR
CLUTCH SHAFT
COUNTERSHAFT DRIVE GEAR
COUNTERSHAFT LOW SPEED GEAR
COUNTERSHAFT REVERSE GEAR
COUNTERSHAFT 3RD SPEED GEAR
COUNTERSHAFT 2ND SPEED GEAR

81.181

Figure 10-6.—Four-speed transmission.


A
B
C
FRONT END
REAR END
MAIN SHAFT
TRANSMISSION MAIN DRIVE GEAR
COUNTER-SHAFT GEARS
1 ST OR LOW
2 ND SPEED
3 RD SPEED
D
E
1
3
2
4
R
SHIFT
F
IDLER GEAR
NO. 4 COUNTERSHAFT GEAR
4 TH OR HIGH
REVERSE

81.182

Figure 10-7.—Power flow through a four-speed transmission.

diagrams to learn what takes place in shifting from one speed to another. For example, as you move the top of the gear shift lever toward the forward left position, the lower arm of the lever moves in the opposite direction to shift the gears. The fulcrum of this lever is in the transmission cover.

In shifting transmission gears it is necessary to use the clutch pedal to disengage the clutch. Improper use of the clutch will cause the gears to clash, and may damage them by breaking the gear teeth. A broken tooth or piece of metal can wedge itself between two moving gears and ruin the entire transmission assembly.

When you shift from NEUTRAL to FIRST or LOW speed (A of fig. 10-7), the smallest countershaft gear engages with the largest sliding gear. LOW gear moves the vehicle at its lowest speed and maximum power. The arrow indicates the flow of power from the clutch shaft to the propeller shaft.

The SECOND speed position is obtained by moving the gear shift lever straight back from the LOW speed position. You will, of course, use the clutch when shifting. In B of figure 10-7, you will see that the next to the smallest countershaft gear is in mesh with the second largest sliding gear. The largest sliding gear (shift gear) has been disengaged. The flow of power has been changed as shown by the arrow. The power transmitted to the wheels in SECOND gear (speed) is less, but the vehicle will move at a greater speed than it will in LOW gear if the engine speed is kept the same.

In shifting from the SECOND speed to the THIRD speed position, you move the gear shift lever through the neutral position. This is done in all selective gear transmissions. From the NEUTRAL position the driver can select the speed position required to get the power he needs. In C of figure 10-7 you will notice that the gear shift lever is in contact with the other shifting fork, and that the forward slide gear has been meshed with the second countershaft gear. The power flow through the transmission has again been changed, as indicated by the arrow, and the vehicle will move at an intermediate speed between SECOND and HIGH.

You shift into FOURTH or HIGH speed position by moving the top of the shift lever back and to the right from the NEUTRAL position. In the HIGH speed position, the forward shift or sliding gear is engaged with the constant speed gear as shown in D of figure 10-7. The clutch shaft and the transmission shaft are now locked together and the power flow is in a straight line. In HIGH, the vehicle propeller shaft revolves at the same speed as the engine crankshaft, or at a 1 to 1 ratio.

You shift to REVERSE by moving the top of the gear shift lever to the FAR right and then to the rear. Most vehicles have a trigger arrangement at the gear shift ball to unlock the lever so that it can be moved from neutral to the far right. The lock prevents unintentional shifts into reverse. Never attempt to shift into reverse until the forward motion of the vehicle has been completely stopped.

Here is where your study of *Basic Machines* will come in handy. *Basic Machines* informs us that an idler gear is used to reverse direction in a gear train. In F of figure 10-7, you can see how the idler gear fits into the transmission gear train. In E of figure 10-7, you can see what happens when you shift into reverse. An additional shifting fork is contacted by the shift lever in the far right position. When the shift to reverse is completed, this fork moves the idling gear into mesh with the small countershaft gear and the large sliding gear at the same time. The small arrows in the inset show how the engine power flows through the transmission to move the propeller shaft and the wheels in a reverse direction.

The different combination of gears in the transmission case makes it possible to change the vehicle speed while the engine speed remains the same. It is all a matter of gear ratios. That is, having large gears drive small gears, and small gears drive large gears. If a gear with 100 teeth drives a gear with 25 teeth, the small gear will travel four times as fast as the large one. You have stepped up the speed. Now, let the small gear drive the large gear, and the large gear will make one revolution for every four of the small gear. You have reduced speed, and the ratio of gear reduction is 4 to 1.

In the transmission just described, the gear reduction in LOW gear is 7 to 1 from the engine to the propeller shaft. In HIGH gear the ratio is 1 to 1, and the propeller shaft turns at the same speed as the engine. This holds true for most all transmissions. The SECOND and THIRD speed positions provide intermediate gear reductions between LOW and HIGH. The gear ratio in SECOND speed is 3.48 to 1, and in THIRD is 1.71 to 1. The gear reduction or gear ratio in reverse is about the same as it is in LOW gear, and the propeller shaft makes one revolution for every seven revolutions of the engine, but in the opposite direction of rotation.

All transmissions do not have four speeds forward, and the gear reductions at the various speeds are not necessarily the same. Passenger cars, for example, usually have only three forward speeds and one reverse speed. Their gear ratios are about 3 to 1 in both low and reverse gear combinations. You must remember that the gear reduction in the transmission is only between the engine and the propeller shaft. Another reduction gear ratio is provided in the rear axle assembly. If you have a common rear axle ratio of about 4 to 1, the gear reduction from the engine of a passenger car to the rear wheels in low gear would be approximately 12 to 1. In high gear the ratio would be 4 to 1, as there would be no reduction of speed in the transmission.

CONSTANT MESH TRANSMISSION

To eliminate the usual transmission noise developed in the old type spur-tooth gears used in the sliding gear transmission, the automotive manufacturers developed the constant mesh transmission which contains helical gears.

In this type of transmission certain countershaft gears are constantly in mesh with the main shaft gears. The main shaft meshing gears are arranged so that they cannot move endwise. They are supported by roller bearings so that they can rotate independently of the main shaft (figs. 10-8 and 10-9).

In operation, when the shift lever is moved to THIRD, the THIRD and FOURTH shifter fork moves the clutch gear (A, fig. 10-9) toward the THIRD speed gear (D, fig. 10-9). This engages the external teeth of the clutch gear with the internal teeth of the THIRD speed gear. Since the THIRD speed gear is rotating with the rotating countershaft gear, the clutch gear must also rotate. The clutch gear is splined to the main shaft, and therefore, the main shaft rotates

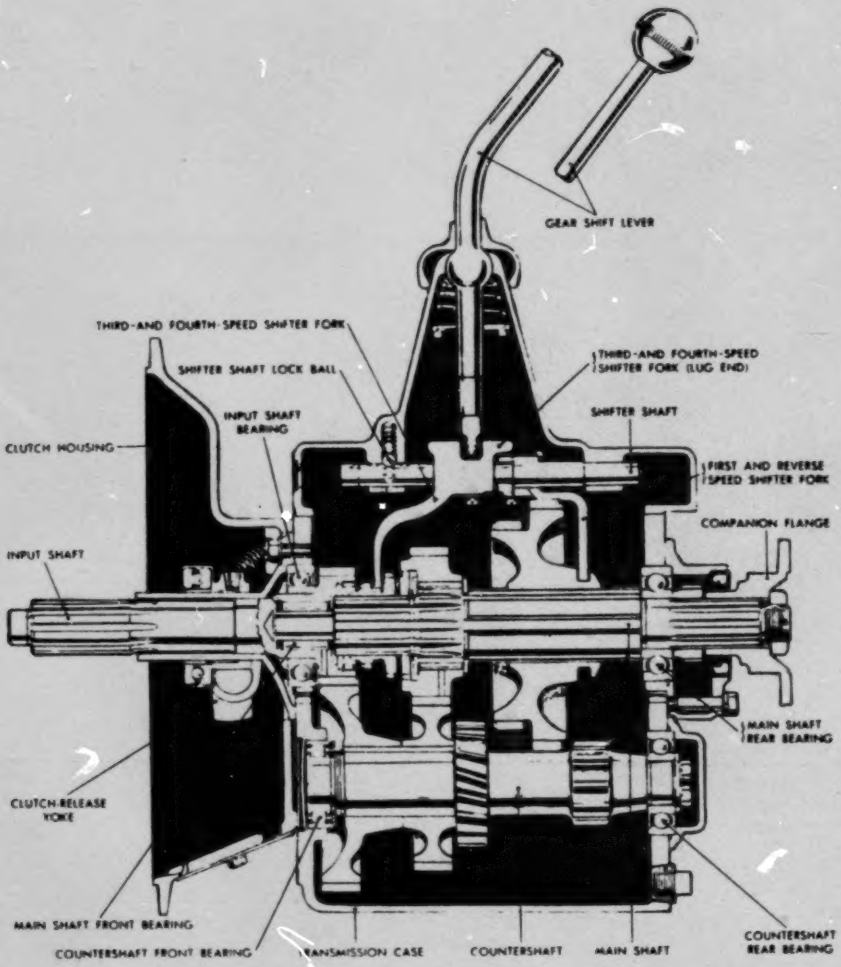
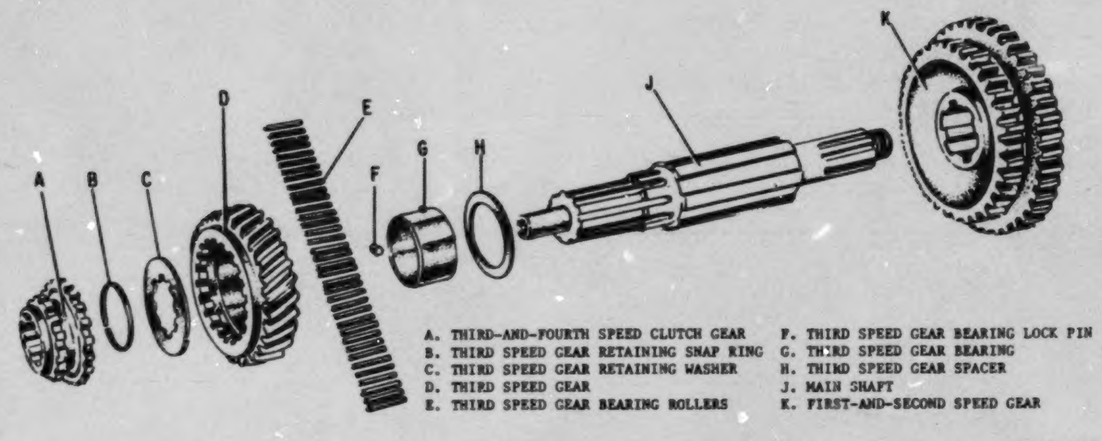

GEAR SHIFT LEVER
THIRD-AND FOURTH-SPEED SHIFTER FORK
SHIFTER SHAFT LOCK BALL
INPUT SHAFT BEARING
CLUTCH HOUSING
INPUT SHAFT
CLUTCH-RELEASE YOKE
MAIN SHAFT FRONT BEARING
COUNTERSHAFT FRONT BEARING
TRANSMISSION CASE
COUNTERSHAFT
MAIN SHAFT
COUNTERSHAFT REAR BEARING
MAIN SHAFT REAR BEARING
COMPANION FLANGE
FIRST AND REVERSE SPEED SHIFTER FORK
SHIFTER SHAFT
THIRD-AND FOURTH-SPEED SHIFTER FORK (LUG END)

Figure 10-8.—Constant-mesh transmission assembly; sectional view. **81.183**


A
B
C
D
E
F
G
H
J
K
A. THIRD-AND-FOURTH SPEED CLUTCH GEAR
B. THIRD SPEED GEAR RETAINING SNAP RING
C. THIRD SPEED GEAR RETAINING WASHER
D. THIRD SPEED GEAR
E. THIRD SPEED GEAR BEARING ROLLERS
F. THIRD SPEED GEAR BEARING LOCK PIN
G. THIRD SPEED GEAR BEARING
H. THIRD SPEED GEAR SPACER
J. MAIN SHAFT
K. FIRST-AND-SECOND SPEED GEAR

81.184

Figure 10-9.—Disassembled main shaft assembly.

with the clutch gear. This principle is carried out when the shift lever moves from one speed to the next.

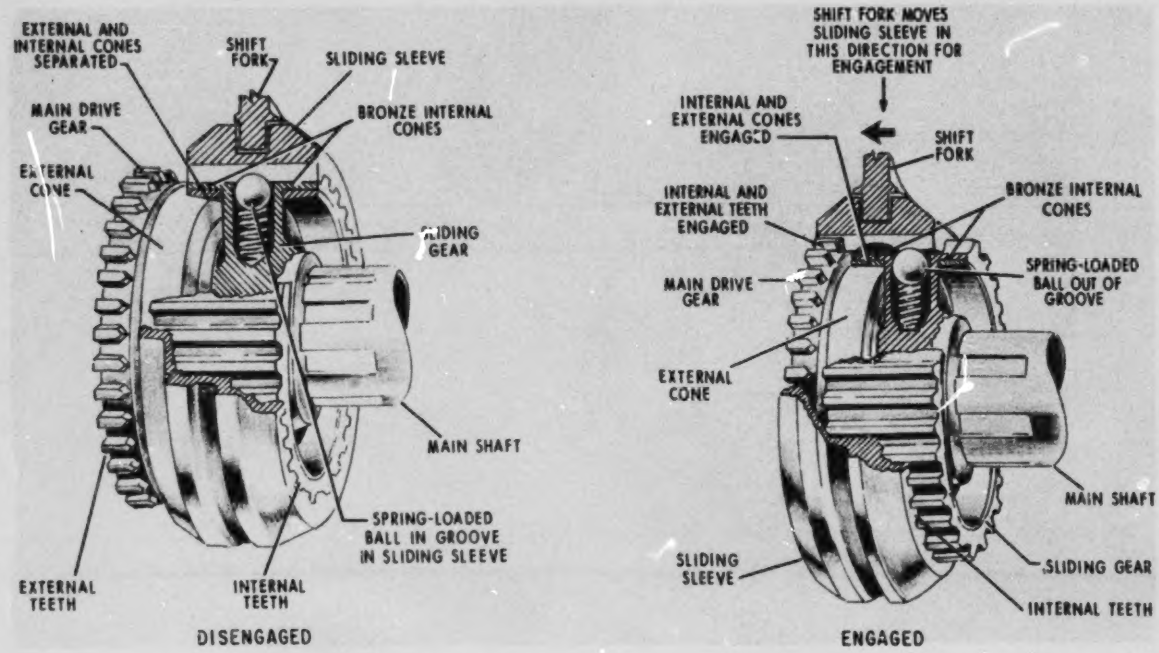
Constant mesh gears are seldom used for all speeds. Common practice is to use such gears for the higher gears, with sliding gears for FIRST and REVERSE speeds, or for REVERSE only.

SYNCHROMESH TRANSMISSION

The synchromesh transmission is a type of constant mesh transmission that permits gears to be selected without clashing, by synchronizing the speeds of mating parts before they engage. It employs a combination metal-to-metal friction cone clutch and a dog or gear positive clutch to engage the main drive gear and second-speed main shaft gear with the transmission main shaft. The friction cone clutch engages first, bringing the driving and driven members to the same speed, after which the dog clutch engages easily without clashing. This process is accomplished in one continuous operation when the driver declutches and moves the control lever in the usual manner. The construction of synchromesh transmissions varies somewhat with different manufacturers, but the principle is the same in all.

The construction of a frequently used synchromesh clutch is shown in figure 10-10. The driving member consists of a sliding gear splined to the transmission main shaft with bronze internal cones on each side. It is surrounded by a sliding sleeve having internal teeth that are meshed with the external teeth of the sliding gear. The sliding sleeve is grooved around the outside to receive the shift fork. Six spring-loaded balls in radially drilled holes in the gear fit into an internal groove in the sliding sleeve and prevent it from moving endwise relative to the gear until the latter has reached the end of its travel. The driven members are the main drive gear and second-speed main shaft gear, each of which has external cones and external teeth machined on its sides to engage the internal cones of the sliding gear and the internal teeth of the sliding sleeve.

The synchromesh clutch operates as follows: when the transmission control lever is moved by the driver to the third-speed or direct-drive position, the shift fork moves the sliding gear and sliding sleeve forward as a unit until the internal cone on the sliding gear engages the external cone on the main drive gear. This action brings the two gears to the same speed and stops endwise travel of the sliding gear. The sliding sleeve then slides over the balls and silently engages the external teeth on the main drive


EXTERNAL AND INTERNAL CONES SEPARATED
SHIFT FORK
SLIDING SLEEVE
MAIN DRIVE GEAR
BRONZE INTERNAL CONES
EXTERNAL CONE
SLIDING GEAR
MAIN SHAFT
SPRING-LOADED BALL IN GROOVE IN SLIDING SLEEVE
EXTERNAL TEETH
INTERNAL TEETH
DISENGAGED
SHIFT FORK MOVES SLIDING SLEEVE IN THIS DIRECTION FOR ENGAGEMENT
INTERNAL AND EXTERNAL CONES ENGAGED
SHIFT FORK
INTERNAL AND EXTERNAL TEETH ENGAGED
BRONZE INTERNAL CONES
SPRING-LOADED BALL OUT OF GROOVE
MAIN DRIVE GEAR
EXTERNAL CONE
MAIN SHAFT
SLIDING SLEEVE
SLIDING GEAR
INTERNAL TEETH
ENGAGED

81.185

Figure 10-10.—Synchromesh clutch—disengaged and engaged.

gear, locking the main drive gear and transmission main shaft together as shown in figure 10-10. When the transmission control lever is shifted to the second-speed position, the sliding gear and sleeve move rearward and the same action takes place, locking the transmission main shaft to the second-speed main shaft gear. In past years it has been the practice of manufacturers not to use the synchromesh clutch on the first or reverse speeds, although it is becoming common practice on many late model vehicles to use synchromesh clutches on first speed. On transmissions of the type that do not use synchromesh clutches on first and reverse speeds, the first speed is engaged by an ordinary dog clutch when constant mesh is employed, or by a sliding gear; reverse is always engaged by means of sliding gear. Figure 10-11 shows a synchromesh transmission in cross section which uses constant mesh helical gears for the three forward speeds and a sliding spur gear for reverse.

Some transmissions are controlled by a steering column control lever (fig. 10-12). The positions for the various speeds are the same as those for the vertical control lever except that the lever is horizontal. The shifter forks are pivoted on bellcranks which are turned by a steering column control lever through the linkage shown. The poppets shown in figure 10-11 engage notches at the inner end of each bellcrank. Other types of synchromesh transmissions controlled by steering column levers have shifter shafts and forks moved by a linkage similar to those used with a vertical control lever.

TRANSMISSION TROUBLESHOOTING

As a first step in transmission service, diagnosis of the trouble should be made to pinpoint the malfunction in the unit. It is not

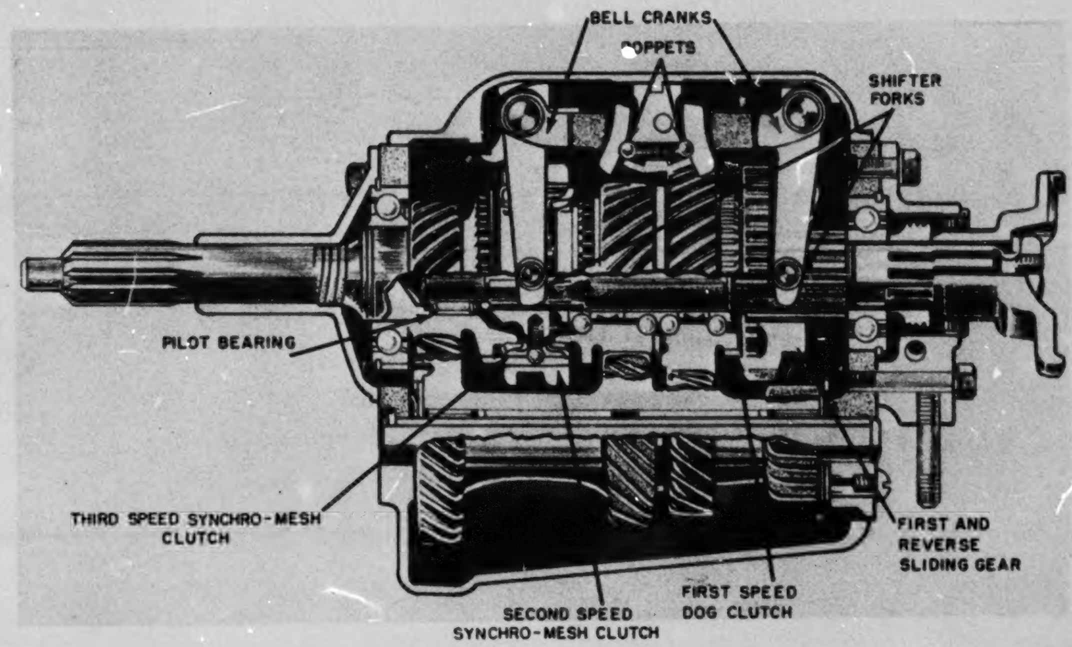
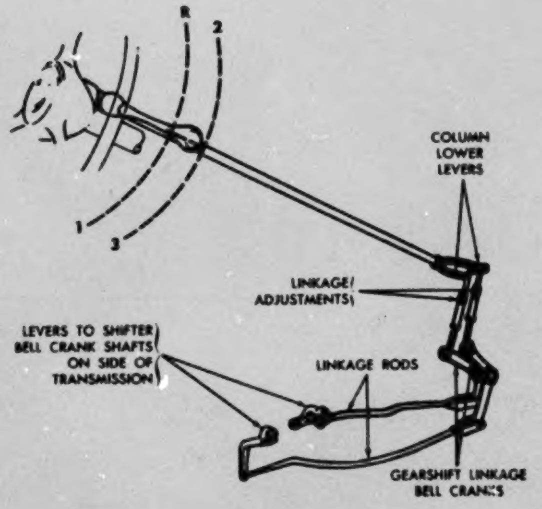

BELL CRANKS
POPPETS
SHIFTER FORKS
PILOT BEARING
THIRD SPEED SYNCHRO-MESH CLUTCH
FIRST AND REVERSE SLIDING GEAR
FIRST SPEED DOG CLUTCH
SECOND SPEED SYNCHRO-MESH CLUTCH

Figure 10-11.—Synchromesh transmission arranged for steering column control. 81.186


R
2
1
3
COLUMN LOWER LEVERS
LINKAGE ADJUSTMENTS
LEVERS TO SHIFTER BELL CRANK SHAFTS ON SIDE OF TRANSMISSION
LINKAGE RODS
GEARSHIFT LINKAGE BELL CRANKS

81.187

Figure 10-12.—Steering column control lever.

always possible to determine the exact location of the trouble, and the unit must be removed from the vehicle so that it can be torn down and examined. In most cases your supervisor will make the final diagnosis if there is any doubt as to the nature of the trouble. Many times an operator will report transmission noise, when, in fact, the noise may be coming from some other component of the vehicle's power train.

Noises that appear to come from the transmission but actually originate at some other point are many and varied. For example, unbalanced propeller shaft, defective wheel bearings, or damaged tires on a vehicle may cause noises which are transmitted to the transmission. These noises have no particular or characteristic sounds that would indicate their origin; they are therefore difficult to identify.

Torsional vibration is one of the most frequent causes of noises that appear to be in the transmission, but actually originate outside of it. Included among these possible outside torsional vibrations are:

1. Propeller shaft (drive shaft) out of balance.
2. Worn universal joints.
3. Drive shaft center bearings loose.
4. Worn and pitted teeth on axle pinion and ring gear.
5. Wheels out of balance.
6. Worn spring pivot bearings.
7. Loose frame or axle U-bolts.
8. Engine cooling fan out of balance.
9. Engine crankshaft, flywheel, and/or clutch plate out of balance.
10. Tires or wheels wobbly or mismatched.

This list, along with other troubles that you have encountered in your own experience, can be used as a step-by-step guide in transmission noise troubleshooting. Make sure that all possibility of outside noise has been eliminated before you remove the transmission.

When analyzing a vehicle for transmission noise, raise the vehicle so that the driving wheels are clear of the deck. Start and operate the vehicle in all the speed ranges, including COASTING with the shift lever in neutral. Listen carefully for noises and try to determine the origin. There are other procedures for checking transmission noises that may be used. Any procedure that is used relies principally on the experience and good judgment of the mechanic doing the troubleshooting.

When it is determined that the noise is within the transmission, generally it is necessary to remove the transmission from the vehicle and disassemble it.

TRANSMISSION OVERHAUL

Because of the variations in construction of transmissions, different procedures in the removal, disassembly, repair, assembly, and installation must be followed. These operations generally require from 5 to 7 hours, depending on the procedure followed. If you are working on a vehicle with which you are not familiar, always check the manufacturer's manual.

Drain the lubricant from the transmission. Some manufacturers recommend flushing the transmission before removal. This is done by filling the transmission with a flushing oil and operating the engine with the transmission in neutral for several minutes. After this, drain the flushing oil from the transmission.

After removing the transmission assembly from the vehicle, note, or mark by scratching the case with a sharp pointed tool, any moist oil spots or unusually heavy accumulation of oil-soaked road mud; these are good clues to the location of small cracks or holes. Do not confuse these accumulations with those that result from leaking gaskets or oil seals. Oil dampness at a gasket or a seal is more or less normal on a transmission that has been in service for any length of time. After marking any spots indicating abnormal oil leakage, thoroughly clean the transmission case and make a close visual inspection to determine if any cracks or holes exist.

After the transmission is disassembled, clean all the parts thoroughly and individually.

Clean away all the parts of hardened oil, lacquer deposits, and dirt, paying particular attention to the small oilholes in the gears and to the lock ball bores in the shifter shaft housing. Remove all gaskets or parts of gaskets, using a putty knife or other suitable tool. Make sure that the metal gasket surfaces are not gouged or scratched.

After all parts of the transmission have been thoroughly cleaned, inspect them to determine whether they can be reused or have to be scrapped. The wear or damage to some of the parts will be evident to the eye, whereas, in others, it may be necessary to use tools or gages to determine their condition. Since the decision as to whether a part should be scrapped or reused is often a matter of opinion or judgment, your supervisor may want to do this job himself.

When inspecting the transmission parts, bear in mind that the inspection procedure has two objectives: first, to eliminate any part or parts that are unsuitable for use, or doubtful parts that may cause the premature failure of the overhauled transmission; second, and equally important, to reduce the wasteful practice of scrapping parts that still retain a high percentage of useful life.

If a transmission part is to be repaired, make sure only good repairs are made. Makeshift or temporary repairs should not be permitted, except in an emergency. The principal purpose of repairs is to salvage parts that would otherwise be scrapped. The decision as to whether a part is to be repaired rests upon the following three factors:

1. The practicality of the repair. (That is, will the repair of the part return it to a near new condition?)
2. The cost of the repair job as compared to the cost of a replacement.
3. The availability of the replacement part. (If replacement parts are unavailable or in short supply, every effort should be made to salvage as many parts as possible.)

Small holes or cracks in the transmission case, shifter shaft housing or clutch housing may be repaired by welding or brazing, provided they do not extend into the bearing bores or mounting surfaces. These pieces are gray (cast) iron, and a special technique is required to weld this material satisfactorily; ordinary welding methods and materials are not suitable.

To assemble a transmission, use a reverse procedure from that of disassembly. Check the manufacturer's manual for proper clearances and the wear limits of the parts. All leather oil seals should be soaked for at least 45 minutes in light oil prior to installation.

All parts, whether new or used, must be lightly coated with medium grade preservative lubricating oil. This is done immediately after inspection or repair. Oiling the parts gives them a necessary rust-preventive coating and facilitates the assembly operations.

Have all the necessary parts and gaskets at hand before the assembly operation begins. This guarantees that the transmission can be completely assembled without interruptions.

Test the transmission after it is assembled. If all parts are correctly assembled, the transmission gears will all rotate freely without evidence of binding. Use a suitable wrench to rotate the input shaft at least 10 full revolutions. Shift the transmission into all the speed ranges. If the transmission is noisy, extremely loose, or binds, it must be disassembled and further corrective measures taken.

TRANSFER CASES

Transfer cases are placed in the power trains of vehicles driven by all wheels. Their purpose is to provide the necessary offsets for additional propeller shaft connections to drive the wheels.

Some transfer cases contain an overrunning sprag unit (or units) on the front output shaft. (A sprag unit is a form of overrunning clutch; power can be transmitted through it in one direction but not in the other.)

On these units the transfer is designed to drive the front axle slightly slower than the rear axle. During normal operation, when both front and rear wheels turn at the same speed, only the rear wheels drive the vehicle. However, if the rear wheels should lose traction and begin to slip, they tend to turn faster than the front wheels. As this happens, the sprag unit automatically engages so that the front wheels also drive the vehicle. The sprag unit simply provides an automatic means of engaging the front wheels in drive, whenever additional tractive effort is required. There are two types of spring unit transfers—a single and a double. Essentially, both types work in the same manner.

The first indication of trouble within a transfer case, as with other components of the power train, is usually "noisy" operation. If an operator reports trouble, make a visual inspection before removing the unit from the vehicle. Check for such things as oil level, oil leakage, and water in the oil.

Make sure the shift lever linkages are inspected. If the shift lever linkages are bent or improperly lubricated, it will be hard to shift the transfer case or in some cases will make shifting impossible. Make sure other possible troubles such as clutch slippage, damaged propeller shaft, and damaged axles have been eliminated.

Worn or broken gears, worn bearings, and excessive end play in the shafts will cause noisy operation of the transfer case. When it is decided that the trouble is within the transfer case, remove the unit from the vehicle for repairs.

Make sure the transfer case is thoroughly cleaned before disassembly of the unit begins. When the unit is disassembled, clean each part with an approved cleaning solvent. Inspection of the individual parts should follow the same procedure as outlined for transmissions. Avoid waste by reusing old parts that are in good condition.

If you are not thoroughly familiar with a particular make and model of transfer case, you should check the manufacturer's repair manual to insure that proper adjustments and assembly procedures are followed.

AUTOMATIC TRANSMISSIONS

The automatic transmission is commonplace in practically all types of automotive and support equipment. Various types of automatic transmissions are being used by the Navy. In most cases the transmission is used with a hydraulic torque converter or a fluid coupling.

The Aviation Support Technician M should become familiar with all phases of the mechanic trade as well as the various automatic transmission systems in use. This is necessary because certain engine defects can interfere with the operation of a transmission, and conversely, certain defects in the transmission will interfere with engine operation. There are even tieups between automatic transmissions and braking systems. Thus, whatever your specialty is as a mechanic–whether you are a fuel injection specialist, carburetor man, or tuneup man, you will be in the dark about much of your job if you do not understand the basic principles of automatic transmissions.

In this section the basic principles by which automatic transmissions operate will be discussed. A good understanding of these basic principles will better enable you to service and repair automatic transmissions.

Most of the fundamentals of hydraulics are put to work in one form or another in the automatic transmission. The automatic transmission uses such hydraulic devices as relief valves, shifter valves, pressure regulators, governors, servo pistons, and many other hydraulic devices which will be discussed in this section.

Advantages and Problems of Hydraulic Systems

Properly constructed hydraulic systems possess a number of favorable characteristics. A hydraulic system is generally simple in construction. It eliminates the need for complicated trains of gears, cams, and levers to transmit motion. In a hydraulic system, motion is transmitted without the slack inherent in the use of solid machine parts. The liquids used are not subject to breakage as are mechanical parts, and the hydraulic mechanism itself is not subject to great wear.

However, there are some special problems associated with hydraulic systems. One of them which pertains to automatic transmissions is that of keeping the hydraulic system dirt free. Dirt, if allowed to accumulate, will clog small passages or score precisely fitted parts. Pressure must be controlled in the system. Excessive movement of the fluid may impair efficiency because of friction within the fluid and against containing surfaces.

Physical Properties of Liquids

While solids always have a definite shape, liquids have no outer form of their own. They quickly conform in shape to their containers. In ease of transmission, liquids are second only to electricity; their shapelessness permits liquids to be lead almost anywhere in a pipe or a hose by means of gravity or by applying forces to them.

Some liquids do not flow as rapidly as others. The slower flowing liquids are said to be more VISCOUS than the faster flowing liquids (glue is more viscous than water). VISCOSITY may be thought of as being the internal friction of a liquid. In the strict sense viscosity is defined as the resistance which a liquid offers to flow. Viscosity increases with decreases in temperature, since liquids always flow less easily when cold than hot. Chapter 11 of this manual discusses the viscosity of oil and how the viscosity of a fluid is measured. The Saybolt Universal Viscometer is used to measure the viscosity of other liquids as well as the oil discussed in chapter 11.

Another property of liquids is their INCOMPRESSIBILITY, at least for all practical purposes. A force of 15 pounds per square inch on a cubic inch of water, for example, will decrease its volume by only 1/200,000; and a force of 32 tons per square inch would reduce a cubic inch of water by only 10 percent.

Other liquids behave similarly. When a force is applied to a confined liquid, the liquid exhibits substantially the same effect of rigidity as a solid. If an appropriate exit is provided, this effect can be combined with fluidity to transmit a force. Thus when we strike the end of a bar, the main force of the blow is carried straight through the bar to the other end because the bar is rigid. (See fig. 10-13.) The direction of the blow almost entirely determines the direction of the transmitted force. The more rigid the bar, the less force is lost inside the bar or transmitted outward at right angles to the direction of the blow.

The foundations of modern hydraulics were laid in 1653 when the French scientist Blaise Pascal discovered that pressure set up in a liquid acts equally in all directions. This pressure acts at right angles to containing surfaces. PASCAL'S LAW is often stated as "Pressure applied to an enclosed fluid is transmitted undiminished to every portion of the fluid and the walls of the containing vessel."

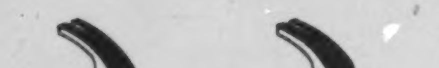


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Figure 10-13.—Transmission of a force through a fluid.

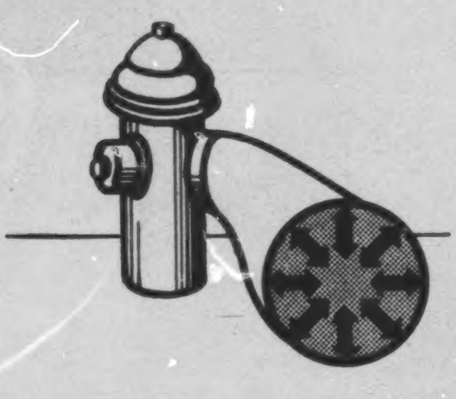
When we apply the force to the end of a column of confined liquid the force is transmitted not only straight through to the other end, but also equally and undiminished in all directions throughout the column—forwards, backwards, and sideways—so that the containing vessel is literally filled with pressure.

For this reason a flat hose takes on a circular cross section when it is filled with water under pressure. The outward push of the water is equal in every direction. (See fig. 10-14.) Water would leave the hose at the same velocity through leaks, no matter on what side of the hose they might happen to be. The velocity right at the point of exit would not be appreciably less in a leak on the upper side of the hose, than a leak on the bottom side.

Pressure and Force in a Hydraulic System

We have just seen that, in accordance with Pascal's Law, any force applied to a confined liquid is transmitted equally in all directions throughout the liquid regardless of the shape of the container. Let us now consider the effect of this physical property upon a modification of the system shown in figure 10-13. Suppose the column of liquid is curved back upward to its original level. (See fig. 10-15.) Here we see two pistons. If we push down on piston 1, a pressure will be created throughout the liquid. (Pressure is defined as force divided by the area over which the force is distributed.) If the force 1 is 100 pounds and the area of the piston is 10 square inches, then the pressure in the liquid is 10 pounds per square inch (10 psi).

The pressure must act also on piston 2, so that for every square inch of its area it will be pushed upward with a force of 10 pounds. In this case we are considering a liquid column of uniform cross section so that the area of piston 2 is the same as piston 1, or 10 square inches. Therefore, the upward force 2 on piston 2 will be 100 pounds, the same as was applied to piston 1. All we have done in this case is to carry our 100-pound force around a bend, but the



81.207

Figure 10-14.—Pressure within a firehose.

principle illustrated underlies practically all mechanical applications of hydraulics.

At this point it should be noted that since Pascal's Law is independent of the shape of the container, it is not necessary that the tube connecting the two pistons should be the full area of the pistons throughout. A connection of any size, shape, or length would do, so long as an unobstructed passage is provided. Therefore the system shown in figure 10-16, wherein a relatively small bent pipe connects two cylinders, would act exactly the same as that shown in figure 10-15.

We have considered hydraulic systems having pistons of equal area in figures 10-15 and 10-16. Let us now consider the situation where the input piston is much smaller than the output piston. (See fig. 10-17.) Let us assume that the area of piston 1 is 2 square inches and the area of piston 2 is 20 square inches. If a force of 20 pounds is impressed on piston 1, there will be a pressure of 10 psi created in the liquid. The force in pounds divided by the area in square inches is equal to the pressure in pounds per square inch. This pressure of 10 psi will act equally at right angles to surfaces in all parts of the container. The upward force on piston 2 will be 10 pounds for each of its 20 square inches of area, or 200 pounds. The ratio between output and input force will always be 10:1 in this system as long as the input force is applied to piston 1.

If the input force is applied to piston 2, the output: input ratio would be 1:10. We can now state the general rule that, because of Pascal's Law, if two pistons are used in a hydraulic system, the force acting on each will be directly proportional to its area, and the magnitude of

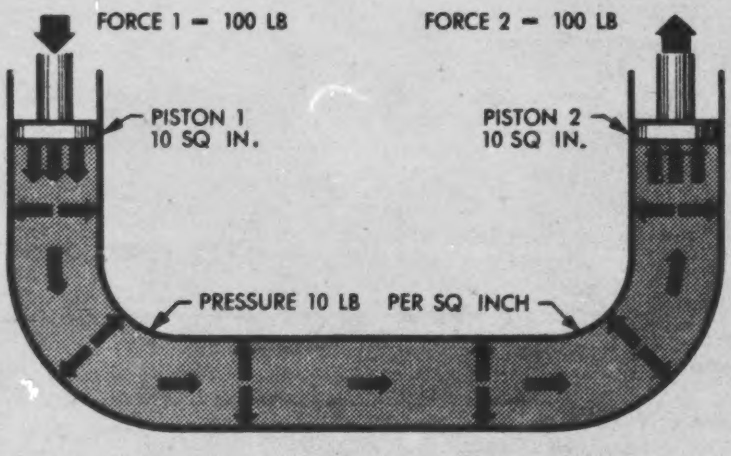


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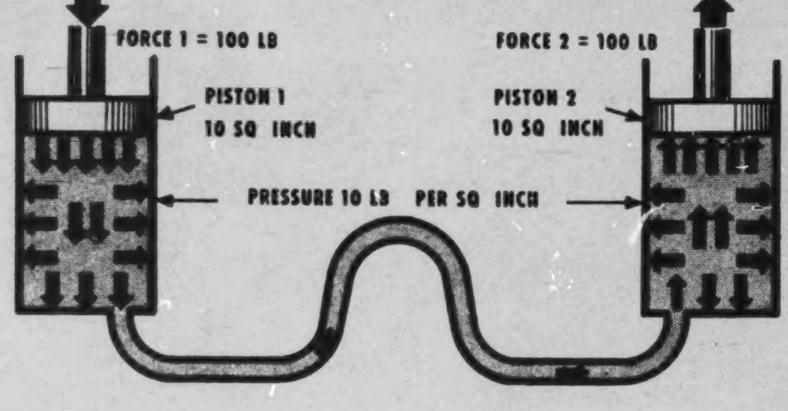
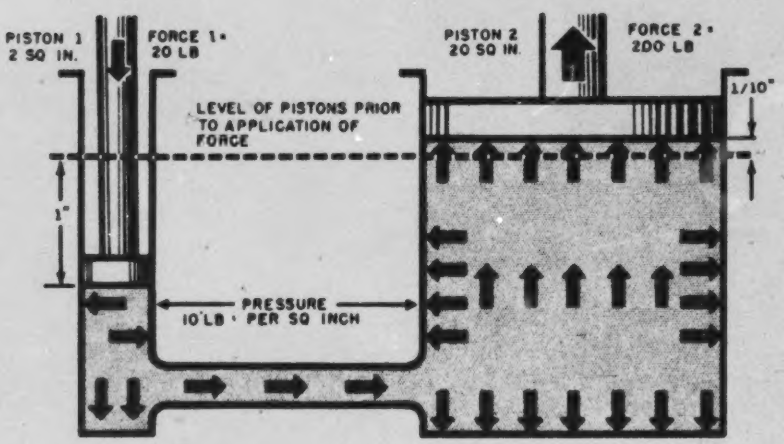
Figure 10-15.—Closed two-cylinder system with equal-sized pistons.


FORCE 1 = 100 LB
FORCE 2 = 100 LB
PISTON 1
10 SQ INCH
PISTON 2
10 SQ INCH
PRESSURE 10 LB PER SQ INCH

81.208

Figure 10-16.—Connecting tube of variable width and shape.


PISTON 1
2 SQ IN.
FORCE 1 = 20 LB
PISTON 2
20 SQ IN.
FORCE 2 = 200 LB
1/10"
LEVEL OF PISTONS PRIOR TO APPLICATION OF FORCE
1"
PRESSURE
10 LB PER SQ INCH

4.7

Figure 10-17.—Closed two-cylinder system with pistons of different size.

each force will be the product of the pressure and its area.

Each of the pistons of the systems illustrated in figures 10-15 and 10-16 is of the same size, 10 square inches. When the input piston is depressed by an inch, 10 cubic inches of liquid are displaced. The other piston is the only other movable object in the system, so the displaced liquid will move the piston enough to accommodate the liquid. In the systems illustrated by figures 10-15 and 10-16 the output piston will move 1 inch to accommodate 10 cubic inches of liquid. In the system of figure 10-17 the output piston will only need to move one-tenth of an inch to accommodate the liquid displaced as piston 1 is depressed by an inch because piston 2's area is 10 times as great as piston 1's area. This leads to the second basic rule for two pistons in the same hydraulic system, which is that the distances moved are inversely proportional to their areas.

FLUID COUPLINGS

You may recall from chapter 4 of this manual that work (measured in ft-lb) is the distance moved multiplied by the force applied and that torque is the turning effort applied (measured in lb-ft).

The simplest means of transmitting torque hydraulically is through a fluid coupling. Fluid couplings can be used with automatic transmissions or with a clutch and standard transmission. In modern vehicles, however, when the fluid coupling is used it is generally used with an automatic transmission.

The fluid coupling consists of two main parts, the driving member of the unit and the driven member. The driving member is called the PUMP and the driven member the TURBINE. Not all manufacturers choose to use these names when writing about the fluid coupling. Sometimes the pump is called the impeller, or driver; the turbine may be called the runner. Often the two members are called FRONT TORUS and REAR TORUS. (A torus is any doughnut-shaped object.) It is important that you become familiar with all these terms so that you can understand the manufacturers' instruction manuals.

The pump of the fluid coupling is connected to the engine and is rotated in the same manner that a crankshaft rotates a flywheel. Usually, the pump is bolted directly to the flywheel. The pump is a torus-shaped object that has fins extending radially from its center. (See fig. 10-18.)

The turbine is made exactly like the pump but is connected to the transmission input shaft. The two members of the coupling face each other within a housing that is filled with the driving fluid (generally oil).

When the pump goes into motion, oil is forced outward by centrifugal force around the entire circumference of the pump and hurled against the blades of the turbine. A continuous flow of oil against the turbine blades is necessary to transfer sufficient kinetic energy to keep a vehicle in motion.

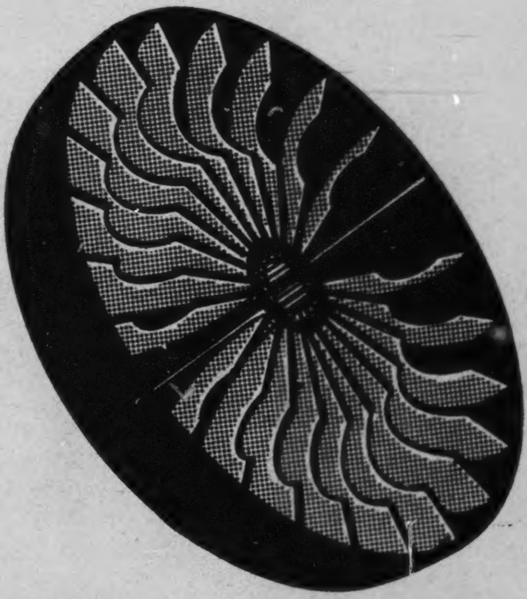

2.204

Figure 10-18.—Fluid drive pump.

The centrifugal force of the oil as it leaves the pump gives the oil the velocity it needs. The faster the pump operates, the more velocity the oil leaving the pump will have. The design of the coupling permits the oil to return to the pump as soon as it has delivered its energy to the turbine.

Where the vehicle has not started to move, the turbine is stationary. For instance, the engine may be rotating the pump at 900 rpm. The pump is consequently imparting energy to the fluid which in turn imparts energy to the turbine. By the time the oil returns to the pump, the pump has moved some distance, making it impossible for the oil to reenter the pump through the same set of vanes it left. Consider one drop of oil; the drop would follow a path that looks something like a string wound around a doughnut through the hole. (See fig. 10-19.) This path of oil is called a vortex and is the path of the stream of oil which drives the turbine.

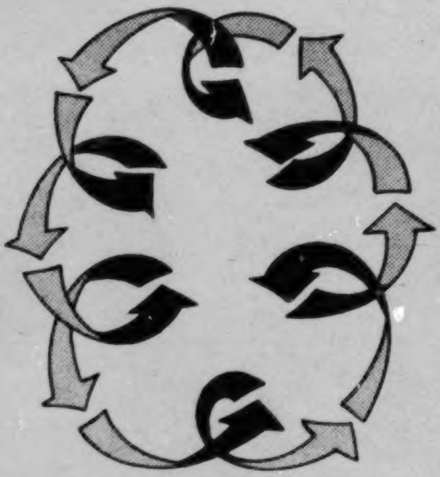


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Figure 10-19.—Schematic of vortex flow in a liquid.

There are as many vortex streams in a fluid coupling as there are fins.

As the turbine begins to turn, the difference in speed between the pump and the turbine decreases. As the speed difference decreases, the coils of the vortex become closer together. A LOW VORTEX exists when the pump and turbine are traveling at nearly the same speed. A HIGH VORTEX exists when the pump and turbine speeds differ greatly.

The higher the vortex, the greater is the driving power of the oil. When the vortex is high, the oil tends to strike the fins on the turbine at nearly a right angle.

The degree of vortex is continually changing and is determined by the difference in speed between the members of the coupling.

A condition known as "Zero Vortex" or "Fluid Coupling Stage" would exist only when the two members of the fluid coupling were turning at exactly the same speed. When this happens the fluid coupling actually has no driving power. The pump, turbine, and the fluid within the coupling are all turning as one unit in a rotary motion.

The fluid coupling stage seldom exists, however, since the turbine will always lag a little behind the pump when there is a load on the vehicle. The fluid coupling stage will exist momentarily when the vehicle begins to coast or reduce speed. As soon as the engine slows down, the momentum of the vehicle will cause the turbine to throw a vortex of oil at the pump, thus permitting the engine to help reduce the speed of the vehicle by creating a drag.

With fluid couplings, shock loads can never be transmitted into the engine. Sudden gear-breaking jerks are impossible. If a vehicle is overloaded, the fluid coupling will slip and will never allow the engine to become overloaded. Thus, harmful low-speed lugging of the engine is impossible. Vibrations and irregularities of the engine can be harmful to the rest of the vehicle's power train. With fluid couplings, it is impossible for these engine irregularities to be transmitted to the power train.

TORQUE CONVERTER

The torque converter may be thought of as a special form of the fluid coupling. The torque converter has driving and driven members with vanes. Oil is passed from the driving to the driven member when the coupling is in operation, thereby transmitting driving force to the driven member.

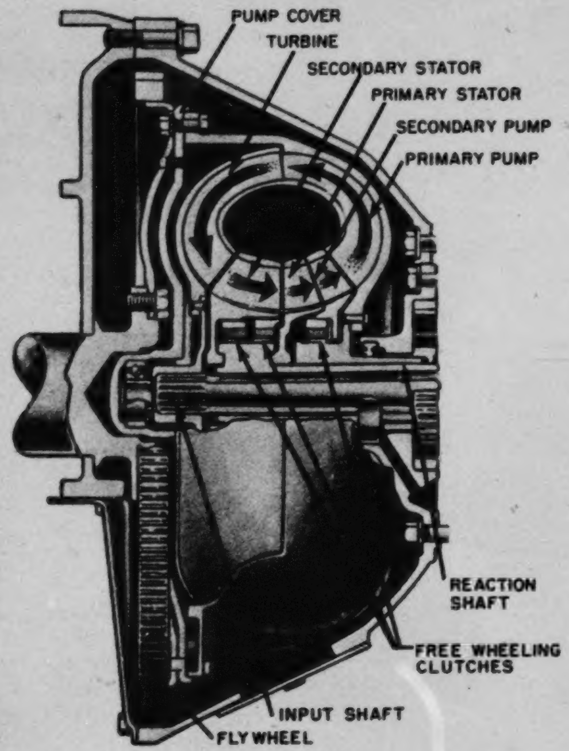
Torque Converter Principles

One of the principal differences between the torque converter and the fluid coupling is that the vanes of the members of the torque converter are curved. Another difference in construction is the addition of other members between the driving and driven members. These additional members are called STATORS. The function of the stators is to redirect the vortex of oil as it returns to the driving member. The returning oil from the driven member would act as a brake on the driving member if the oil and the driving member did not have the same direction. The vortex helps to drive the pump rather than opposing the pump.

The torque converter not only acts as a fluid coupling but also provides a speed-producing, torque-multiplying connection between the driving and the driven shafts. It can actually take the place of the conventional transmission since, with a torque converter, there is no need for manual gear shifting. The vehicle can be accelerated from a standing stop to high speed with the torque converter providing, in effect, the varying gear ratios. In actual practice, however, the torque converter is used with a gear system to provide an optimum speed/torque combination.

Operation of the Torque Converter

The primary operation of the torque converter is the result of the oil's being passed from the pump to the turbine. The oil pushes against the faces of the turbine vanes, causing the turbine to rotate in the same direction as the pump. If the pump is rotating much more rapidly than the turbine, the oil enters the turbine and pushes against the turbine vanes with great force. See figure 10-20 for a partial cutaway view of the torque converter.

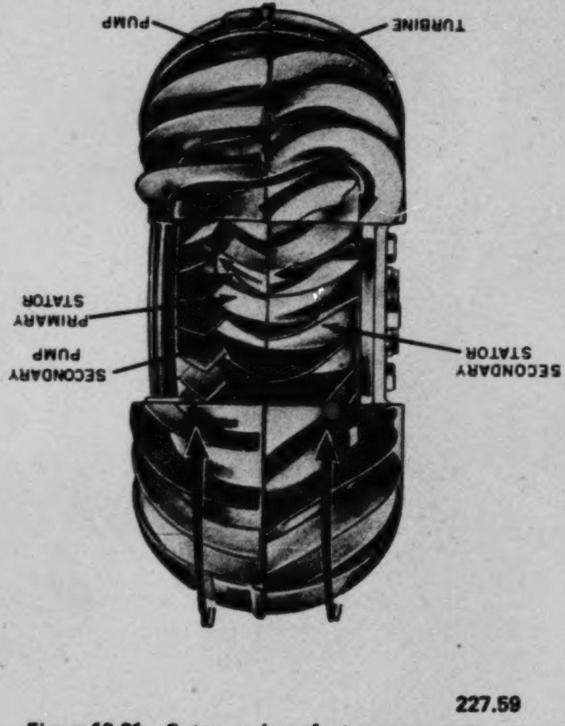

PUMP COVER
TURBINE
SECONDARY STATOR
PRIMARY STATOR
SECONDARY PUMP
PRIMARY PUMP
REACTION SHAFT
FREE WHEELING CLUTCHES
INPUT SHAFT
FLYWHEEL

227.58

Figure 10-20.—Torque converter (arrows show direction of flow) - partial cutaway view.

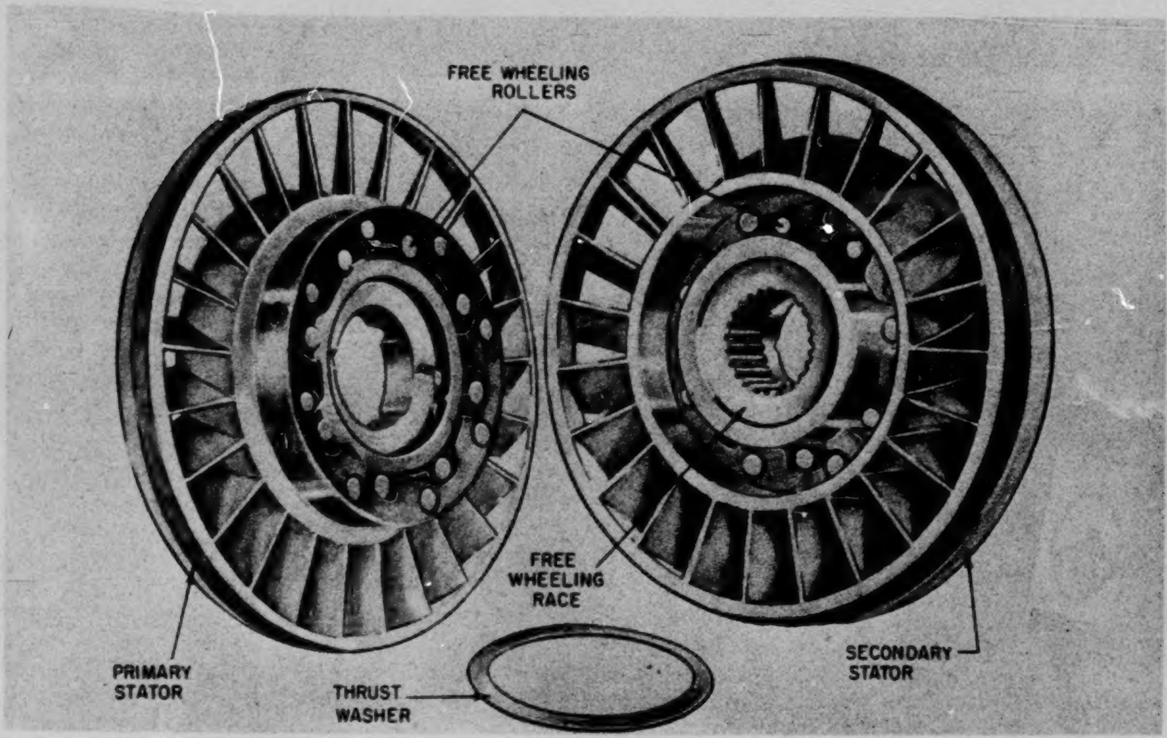
As the oil passes through the turbine, it imparts force all along the turbine vanes. But the oil does not give up all of its force of motion to the turbine vanes. The oil still has considerable energy, even though while passing through the turbine it has reversed its direction of motion as shown in figure 10-21. If this direction of motion were not changed, the oil would reenter the pump in a direction opposing pump rotation. The oil would then act as a brake on the pump, slowing the pump down. Considerable engine power would be required to overcome the braking force of the oil pressure. The additional members in the torque converter are placed so that they can overcome this action by again changing the direction of the oil before it reenters the pump, thereby avoiding loss of power.

As can be seen in figure 10-20 and in the central portion of figure 10-21, the curved


PUMP
TURBINE
PRIMARY STATOR
SECONDARY PUMP
SECONDARY STATOR

227.59

Figure 10-21.—Cutaway view of a torque converter showing curvature of vanes and direction of oil flow.



227.60

Figure 10-22.—Primary and secondary stators showing freewheeling rollers.

blades of the added members (secondary stator and primary stator, fig. 10-22) reverse the direction of the oil into a forward, or helping, direction before the oil reenters the pump. The oil is once more passed into the turbine from the pump, adding more "push" to the turbine vanes. During this action the stators are stationary and act simply as oil direction reversers.

It is this continuous passing of the oil from the pump into the turbine, back to the pump where the oil picks up more energy of motion, and then back into the turbine again, that produces the torque multiplication. Repeated application of this push increases the total push so that when the turbine is rotating at very slow speed with the pump rotating at high speed, the torque at the output shaft (attached to the turbine) may be several times the torque at the input shaft (attached to the engine).

In actual operation, the secondary stator and primary stator are stationary when there is a great difference between pump and turbine speed. The secondary pump (fig. 10-20) is overrunning, or running faster than, the primary pump and does not enter into the converter action at all at this time.

When the turbine is stopped or turning slowly and the pump is turning rapidly, the direction of the oil flow is shown in figure 10-21. As the oil moves to the secondary pump (at the right of the central portion of fig. 10-21), the oil strikes the back sides of the secondary pump vanes, pushing the secondary pump ahead so that the secondary pump overruns. Under this condition the secondary pump vanes are simply moving out of the way of the oil. The secondary pump enters the action when the pump and turbine are turning at about the same speeds.

The secondary pump is mounted on a freewheeling or overrunning clutch. The freewheeling clutch permits the secondary pump to run freely in one direction, but when the secondary pump attempts to slow down below shaft speed, the freewheeling clutch locks on the shaft as the rollers (fig. 10-22) jam between the race and the hub.

When the turbine speed increases to the point at which the turbine turns at nearly the same speed as the pump, the oil leaves the turbine vanes with less of the reverse direction. As a consequence, the oil begins to strike the backsides of the secondary stator vanes so that the secondary stator begins to overrun on its overrunning clutch. The secondary stator is no longer needed; therefore, in effect, the secondary stator moves out of the way by overrunning or freewheeling.

When turbine speed increases to nearly pump speed, as when cruising at steady speed along the highway, the oil leaves the turbine vanes with very little reverse direction of motion. The primary stator also begins to overrun, since the oil begins to strike the back sides of its vanes. The oil begins to strike the front faces of the secondary pump vanes at the same time. The secondary pump stops overrunning and slows to primary pump speed. The secondary pump now helps the primary pump, and the two work together as a unit. Under these conditions, the torque converter functions like a fluid coupling.

The unit we have described is a five-member torque converter with a primary pump, turbine, primary stator, secondary stator, and secondary pump. Other torque converters have only four members, while still others have only three. In every case the added units have the job of reversing the direction of oil movement as the oil leaves the turbine when there is considerable difference in turbine and pump speeds. In addition to these variations some torque converters have a lockup clutch that locks out the converter above a certain speed. The clutch acts much like a conventional clutch, but the clutch does not engage until a certain speed is reached. As the clutch engages, the clutch locks out the torque converter and thereby prevents any slippage between the driving and driven shafts.

Since torque converters vary considerably in design, the amount of torque multiplication they can achieve also varies. Practical limits are about 5:1. Many torque converters provide satisfactory operation with a much lower torque multiplication (some passenger car units provide less than 2.5:1).

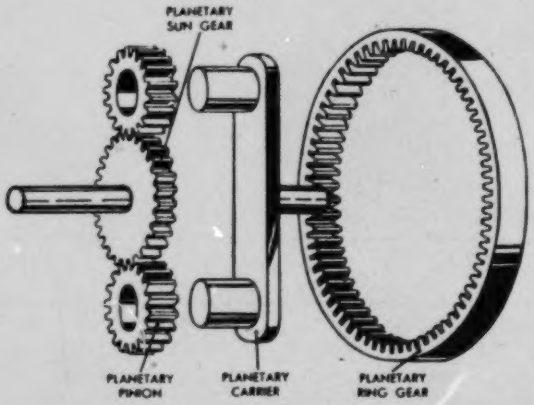
PLANETARY GEARS

Automatic transmissions use a system of planetary gears to enable the torque from the torque converter or fluid coupling to be used as efficiently as possible.

The planetary units are the heart of the modern automatic transmission. An understanding of the power flow through the planetary units is essential to the understanding of the operation of the automatic transmission.

Members of the Planetary Gear System

Four basic parts make up the planetary gear system. These basic parts are the sun gear, the ring (or internal) gear, the planet pinions, and the planet carrier. Their relationship is illustrated in figure 10-23. The sun gear is so named because it is the center of the system. The planet pinions,



2.209

Figure 10-23.—Members of a simple planetary gear system.

or planet gears, are called planets because they rotate around the sun gear shown in figure 10-23. The ring gear, or internal gear, is so called because of its shape and because it has internal teeth.

There are several advantages inherent in the planetary gear system. One of the advantages is the compactness of the system. Another advantage is that there is more tooth contact to carry the load, since each gear of the planetary system is usually in contact with at least two other gears of the system. (See fig. 10-23.) The gears are always in mesh. There can be no tooth damage due to tooth clash or partial engagement. The big advantage is the one which makes it so popular: namely, the ease of shifting gears. Planetary gear sets in automatic transmissions are shifted without any skill on the part of the driver.

There are various ways in which power may be transmitted through the planetary gear set. A shaft from the engine may be connected to drive the sun gear, it may be connected to drive the planet carrier, or it may be connected to drive the ring gear. The propeller shaft that ultimately drives the wheels of the vehicle also may be connected to any of these members. Power can be transmitted in the planetary gear system when:

1. The engine is delivering power to one of the three members.
2. The propeller shaft is connected to one of the other members.
3. The remaining member is held against rotation.

All three conditions must be satisfied for power to be transmitted in the system. Automatic transmissions provide the means for holding a member through hydraulic servos or spring pressure.

Power Transmission Through a Planetary System

Power can be transmitted through a planetary system under eight sets of conditions.

CASE ONE–MAXIMUM REDUCTION.–In the first set of conditions the engine is driving the sun gear; the propeller shaft is connected to the planet carrier; and the ring gear is held against rotation. (See fig. 10-24.) The planet gears are meshed with the sun gear. The planet gears rotate on their shafts (the planet gears are always free to rotate on their own shafts). The ring gear is held stationary, forcing the planetaries to "walk around" the inside of the ring gear. When the planet pinions walk around the ring gear, they rotate the planet carrier on its center. If the ring gear were not held stationary, the planets would spin on their shafts and rotate the ring gear. Because the propeller shaft is connected to the planet carrier, it rotates with the planet carrier. In this case, the propeller shaft rotates in the same direction as the crankshaft, but the two shafts do not rotate at the same speed.

To calculate the speed ratio between the crankshaft and the propeller shaft, add the total number of teeth on the ring gear to the total number of teeth on the sun gear. Then divide the number of teeth on the sun gear into that number. The speed ratio (ENGINE SPEED TO PROPELLER SPEED) may be expressed algebraically as $(R + S):S$ where S is the number of teeth in the sun gear and R is the number of teeth in the ring gear. For instance, if the sun gear has 18 teeth and the ring gear 36, the total is 54. Divide 18 into 54, and the answer is 3. This means the sun gear must rotate three times in order to rotate the planet carrier once.

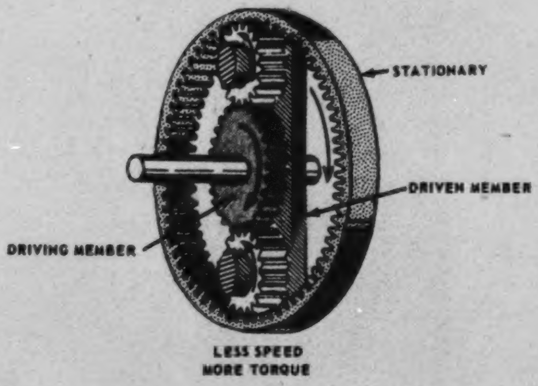


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Figure 10-24.—Planetary gears in maximum reduction.

CASE TWO–MINIMUM REDUCTION.–Minimum reduction in the planetary gear set takes place when the ring gear is driven by the engine and the propeller shaft is connected to the planet carrier (fig. 10-25). The sun gear is held against rotation. The rotation of the ring gear forces the planets to walk around the sun gear. The planetary carrier is rotated in the same direction as the engine. The attached propeller, or output, shaft is rotated in the same direction as the planetary carrier. There is a speed reduction from the crank shaft to the output shaft.

The speed reduction is not of the same magnitude as the speed reduction in case one. The speed reduction may be calculated by adding the number of teeth in the sun gear to the number of teeth in the ring gear and dividing the total into the number of teeth in the ring gear. The result of $R \div (R + S)$ is then compared to unity (one). Note that when we speak of a speed reduction or a speed increase (discussed later), we are comparing the output from the transmission with the input to the transmission. The ratio we speak of is the ratio of the input to the transmission to the output from the transmission (input:output). The ratio for case two is $(S + R):R$. If the sun gear has 18 teeth and the ring gear 36, this would make a total of 54. Divide 36 into 54 and the answer is 1 1/2. This means the engine must rotate the ring gear 1 1/2 times in order to rotate the planet carrier once. The ratio is 1 1/2:1 and the reduction through the transmission is 1/3 (the output is 2/3 of the input).

CASE THREE–REVERSE REDUCTION.–When a reverse reduction is desired, the engine is made to drive the sun gear; the propeller shaft is connected to the ring gear; and the planet carrier is held stationary. (See fig. 10-26.) The sun gear is driven in the same direction of rotation as the engine (clockwise), thus causing the planet gears to rotate counterclockwise. Since the planet carrier is held stationary, the planet gears rotate on their shafts and cause the ring gear to rotate in an opposite direction from the sun gear. The gear reduction, in this case, is a direct ratio of the number of teeth on the ring gear to the number of teeth on the sun gear. For example, if the ring gear has 36 teeth and the sun gear 18, the speed reduction will be one-half. The planetary gears merely idle and do not influence the speed ratio. The ratio may be expressed algebraically as $R:S$.

CASE FOUR–MINIMUM OVERDRIVE.–This case is opposite to case two. As shown in figure 10-27, the engine drives the planet carrier, and the output is taken from the internal (ring) gear. The sun gear is held against rotation. The driving and driven members have changed places. The result is an

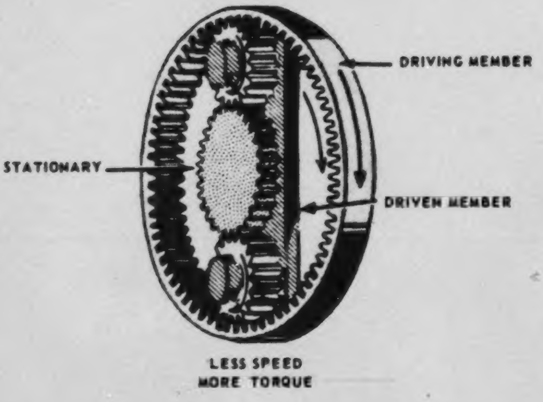

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Figure 10-25.–Planetary gears in minimum reduction.

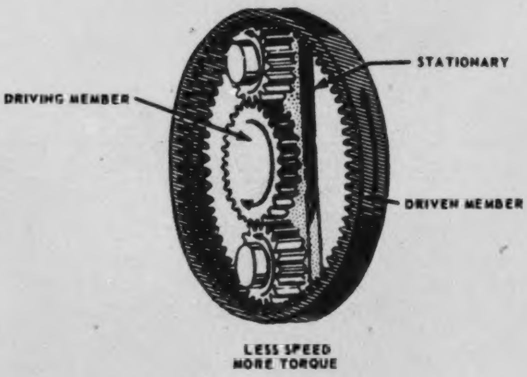

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Figure 10-26.–Planetary gears in reverse reduction.

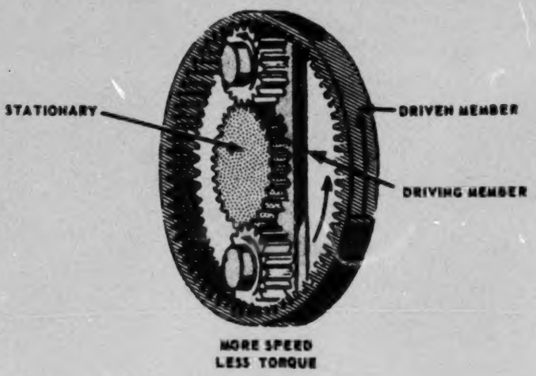

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Figure 10-27.—Planetary gears in minimum overdrive.

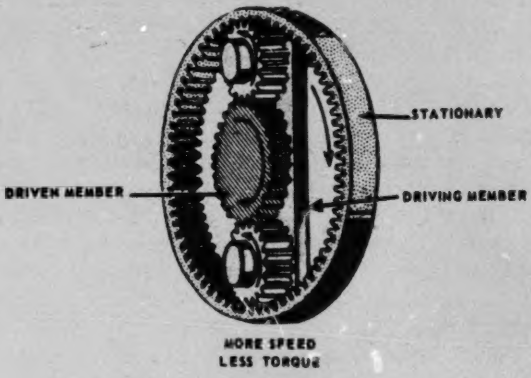

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Figure 10-28.—Planetary gears in maximum overdrive.

increase in speed from the input shaft to the output shaft instead of a reduction in speed.

The algebraic expression for the speed increase, (S + R) ÷ R, is the inverse of the one for minimum speed reduction. Instead of having a speed ratio of 1 1/2:1, we now have a ratio of 1:1 1/2. The engine will rotate once for every one and one-half times that the propeller shaft is rotated. A minimum overdrive is the type usually found in automotive equipment that has an overdrive incorporated in the transmission.

CASE FIVE–MAXIMUM OVERDRIVE.–Another means of obtaining an overdrive effect is possible in the planetary gear system. Case five uses the driven member of case one as the driving member and the driving member of case one as the driven member. As shown in figure 10-28, the engine is connected to the planet carrier and the sun gear is connected to the propeller shaft. The ring gear is held against rotation. Instead of maximum reduction we have maximum overdrive.

The algebraic formula for the speed increase is the reciprocal, or inverse, or the algebraic expression for the speed reduction of case one. The formula is (S + R) ÷ S. Assuming the same number of teeth as in case one for the members of the gear system, the ratio would be 1:3. The engine will rotate one time while the propeller shaft is rotating three times.

CASE SIX–REVERSE OVERDRIVE.–The reverse overdrive condition has little practical value and is included only to cover all of the possible combinations of a planetary gear set. The engine is connected to the ring gear, and the propeller shaft is connected to the sun gear. The planetary carrier is held against rotation. The sun gear is forced to rotate in a counterclockwise direction. The speed increase will be two to one if the ring gear has 36 teeth and the sun gear has 18 teeth.

Reverse overdrive is opposite to reverse reduction. The speed increase would be expressed algebraically as R/S. The ratio would be 1:2. The engine will rotate once while the propeller shaft is rotating twice. There is no advantage for a vehicle to have a speed increase in reverse.

CASE SEVEN–DIRECT DRIVE.–If direct drive is desired, no member of the planetary gears is held to prevent rotation. A direct drive can be obtained regardless of which member is being driven or which member is the driving member. As an example consider the situation where the driving member is the sun gear and the driven member is the planet carrier as in figure 10-24. Instead of locking the ring gear, leave it free to rotate and lock the ring to the sun gear. If this condition existed, the entire unit would rotate and as a result a one-to-one ratio from the engine to the propeller shaft would exist.

Any two of the members may be locked together to obtain direct drive. There is no speed increase or decrease within the system (1:1 ratio). The engine will rotate once as the output shaft rotates one time.

CASE EIGHT–NEUTRAL.–In the last possible combination for a planetary gear set, no member is held against rotation or locked to another member. When no member is held to take torque reaction there can be no power transmitted through the planetary system. The planetary carrier may be driven, but if the sun gear is not held there will be no minimum overdrive condition. The sun gear will rotate, making it impossible for the planets to walk around the sun gear. The planets have to walk around the sun gear to drive the ring gear to obtain minimum overdrive.

A tabular summary of the possible planetary combinations discussed in the eight cases is provided in table 10-1. The algebraic expressions for the speed of the propeller shaft where there is a speed reduction or increase are listed in table 10-2.

AUTOMATIC TRANSMISSION CONTROL SYSTEM

Provision must be made within the automatic transmission system for the transmission to shift automatically from one gear range or ratio to another as the speed and power requirements of the vehicle and the demands of the driver vary. The means of mechanical control is to connect a control device to the hand lever operated by the driver. The speed of the vehicle can regulate the selection of the gear ratio to be used under normal operating conditions as follows: slow speed requires a low gear ratio; fast speed requires a high gear ratio. To do this, a governor driven by the engine or the drive shaft selects the gear ratio in relation to the speed of the vehicle.

Table 10-1.–Tabular summary of the possible combinations of a planetary gear set

CASE	STATIONARY MEMBER	DRIVING MEMBER	DRIVEN MEMBER	RESULT
ONE	RING	SUN	CARRIER	MAXIMUM REDUCTION
TWO	SUN	RING	CARRIER	MINIMUM REDUCTION
THREE	CARRIER	SUN	RING	REVERSE REDUCTION
FOUR	SUN	CARRIER	RING	MINIMUM OVERDRIVE
FIVE	RING	CARRIER	SUN	MAXIMUM OVERDRIVE
SIX	CARRIER	RING	SUN	REVERSE OVERDRIVE
SEVEN	NONE (TWO HELD TOGETHER)	ANY	ANY	DIRECT DRIVE
EIGHT	NONE	ANY	NONE	NEUTRAL

Table 10-2.—Algebraic expression for determining the relative speeds of the planetary gear members

PLANETARY GEAR SPEEDS

S = Number of Teeth in Sun Gear = 18 (text example)

R = Number of Teeth in Ring Gear = 36 (text example)

C = Planet Carrier

CASE	STATIONARY MEMBER	DRIVING MEMBER	DRIVEN MEMBER	SPEED RATIO ENGINE: PROPELLER		RELATIVE SPEED OF THE DRIVEN MEMBER	
					text example		text ex.
ONE	R	S	C	R + S:S	36 + 18:18 54:18 3:1	S/R + S	1/3
TWO	S	R	C	S + R:R	18 + 36:36 54:36 1 1/2:1	R/S + R	2/3
THREE	C	S	R	R:S	36:18 2:1	S/R	1/2
FOUR	S	C	R	R:R + S	36:36 + 18 36:54 1:1 1/2	R + S/R	3/2
FIVE	R	C	S	S:S + R	18:18 + 36 18:54 1:3	S + R/S	3/1
SIX	C	R	S	S:R	18:36 1:2	R/S	2/1
SEVEN	NONE	ANY	ANY	1:1		1/1	
EIGHT	NONE	ANY	NONE	---		0	

Another method of controlling the transmission automatically is to do so by the load on the engine. Because the vacuum in the manifold decreases as the load on the engine is increased, this can be done by connecting a valve to the engine intake manifold. Another method is to have a valve or valves operated hydraulically by means of oil pressure generated in the engine or in the transmission by oil pumps.

Traffic and terrain conditions are such that the vehicle speed or engine load is not always the desired method of choosing the gear ratio to be used. The matter of gear ratio selection and shifting must be under the control of the driver. The driver's demands are expressed by the amount he advances the accelerator. Suddenly depressing the foot accelerator when the vehicle is moving will cause the transmission to shift to a lower gear ratio in order to permit more rapid acceleration. Should the vehicle be accelerating in a condition at less than full throttle the control action of the automatic transmission normally would shift into a higher gear ratio at a certain speed. If the accelerator is depressed just as this speed is reached, it is linked to the automatic transmission in such a way that the shift will be overcome and permit rapid acceleration of the vehicle in the lower range instead of shifting into a higher gear.

More than one of these control devices may be combined in a system in order to obtain almost any kind of automatic control desired. It is often desirable to attach more than one control to a valve in order to balance the action. For example, a valve might have dual controls–one to the foot accelerator and one to the intake manifold. In this case the valve can be opened or closed by movement of the accelerator, provided that the engine is under light load. If the engine is under heavy load, the shift that would normally take place by action of the accelerator would be delayed by the interconnected vacuum control until the engine load decreases. Adjustment to speed and load and the demands of the driver are automatically made in the transmission ratios by appropriate connection of different controls to the shifting valves in the transmission.

In modern automatic transmissions the automatic shifting is accomplished through a system of hydraulic valves or servo units operating clutches and/or bands. A pump or pumps develop hydraulic pressure that is directed by the control valves to clutches and/or bands that control the gears in the automatic transmission and cause the shifting from one ratio to another. The operation of the various control valves is a mechanical balance controlled by the position of the hand lever, governor pressure, throttle valve pressure, engine vacuum, or return spring pressure. The control system operates on a balanced pressure plan. Springs are balanced against varying pressures and speeds until a very sensitive and responsible control is obtained over the transmission mechanism.

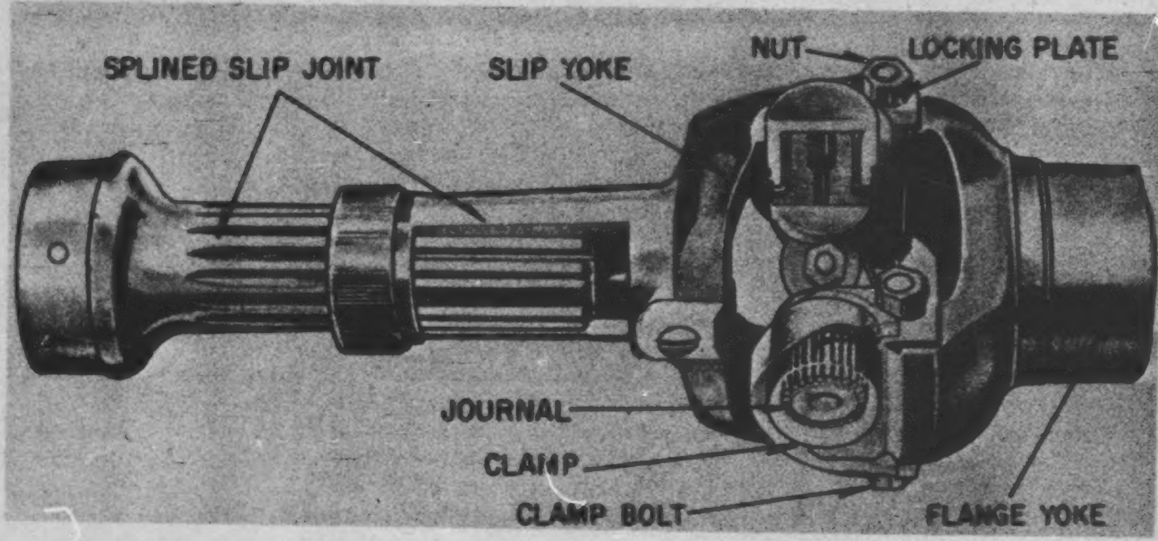
MAINTENANCE AND REPAIR

The procedures for the maintenance and repair of automatic transmissions will vary considerably among makes and models of transmissions. For this reason no procedures for maintenance and repair are presented in this manual. It is stressed that, when repairs are to be performed, you follow the specific procedures as outlined in the manufacturer's maintenance manual for the transmission being repaired. Adjustments to automatic transmissions must be made accurately to obtain proper operation of the unit.

PROPELLER SHAFT ASSEMBLIES

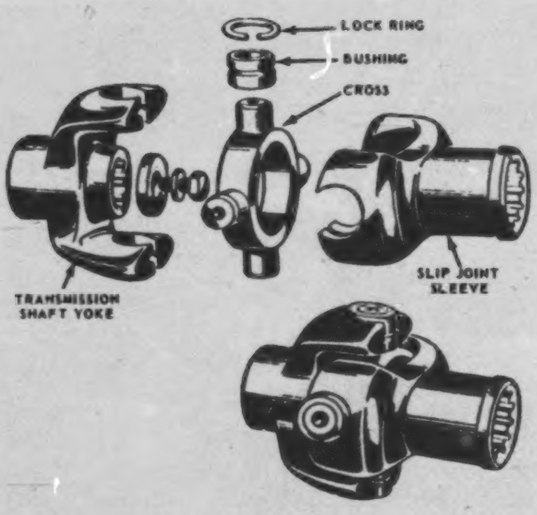
The propeller shaft assembly consists of a propeller shaft, a slip joint, and one or more universal joints. The propeller shaft is a driving shaft that transmits the power from the transmission to the differential. The slip joint (fig. 10-29) is necessary because the movement between the transmission and the differential requires that the propeller shaft be able to shorten or lengthen itself. On vehicles having rear springs the differential moves up and down as the rear wheels move over uneven surfaces. This up and down movement lengthens and shortens the distance between the transmission and the differential. On vehicles such as tow tractors that have no rear springs, the slip joint is necessary because the distance between the transmission and the differential still increases and decreases when the vehicle moves over uneven surfaces. Vibration of the engine on its shock mounts and expansion and contraction also necessitate a slip joint.

Because the differential is situated below the level of the transmission, universal joints are necessary to permit the change of direction of drive. The usual type of slip joint consists of a splined shaft that fits into a splined sleeve as shown in figure 10-29. The splines permit the continuing transmission of power as the sleeve moves back and forth on the shaft. A universal joint is essentially a double-hinged joint consisting of a Y-shaped yoke on the driven shaft, another Y-shaped yoke on the driving shaft, and a cross-shaped member called the spider. Figure 10-30 shows a common universal joint. Two of the four arms (trunnions) of the spider fit into bearings in the end of the driving shaft yoke, and the other two arms (trunnions) are assembled in the end of the driven shaft yoke. When the two shafts are at an angle


SPLINED SLIP JOINT
SLIP YOKE
NUT
LOCKING PLATE
JOURNAL
CLAMP
CLAMP BOLT
FLANGE YOKE

2.200

Figure 10-29.—Slip joint and universal joint.


LOCK RING
BUSHING
CROSS
TRANSMISSION SHAFT YOKE
SLIP JOINT SLEEVE

81.194

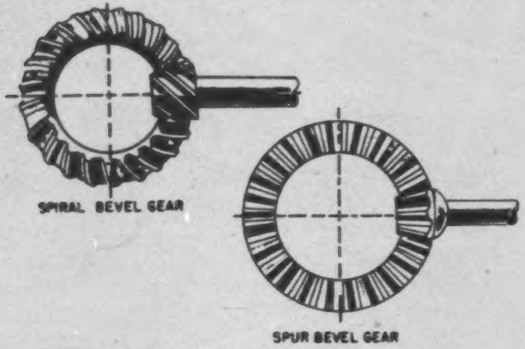
Figure 10-30.—Common type of universal joint.

to each other the bearings in the yokes permit the yokes to swing on the trunnions with each revolution. Universal joints may have roller bearings around the trunnions as shown in figure 10-29.

Slip joints and universal joints require little maintenance except lubrication where fitted with grease fittings. They may be factory packed with grease and not need lubrication. Propeller shafts may be solid or tubular. Tubular shafts are used when the transmission is some distance from the differential. Solid shafts are usually used on tow tractors because the shaft is very short.

DIFFERENTIALS

The differential is connected to the propeller shaft by the final drive. The final drive consists of a pinion gear driven by the propeller shaft. The pinion turns a ring gear that is part of the differential. The function of the ring gear and pinion is to change the direction of the power


SPIRAL BEVEL GEAR
SPUR BEVEL GEAR

81.195

Figure 10-31.—Ring gear and pinion.

transmitted through the propeller shaft by 90 degrees in order to drive the axles. The ring gear and pinion also provide fixed reduction between the speed of the propeller shaft and the axles. The gear ratio is determined by dividing the number of teeth on the ring gear by the number of teeth on the pinion.

Most aviation support equipments have bevel gears (fig. 10-31) in the final drive. Spur bevel gears are very noisy; therefore, spiral bevel gears are used on most equipment. The ring gear and pinion are housed in the differential housing and lubricated by the grease therein.

The purpose of the differential is to adjust for the difference in distance the driven wheels travel when the vehicle turns. For example, if a 90-degree turn was made on a 20-ft radius, the inner wheel would travel about 31 ft and the outer wheel would travel nearly 39 ft. The differential permits each axle to turn at a different rate and still be driven as a single unit.

CONVENTIONAL DIFFERENTIAL

The drive pinion, connected to the propeller shaft, rotates the drive ring gear and the differential case which is attached to it. (See fig. 10-32.) When both wheels are rotating at the same speed, as they do on a smooth straight surface, the differential pinions do not rotate on their trunnions but serve to lock the drive ring gear and differential case with the differential side gears and axles, making them turn as one unit. In this case there is no relative motion between the drive ring gear and the axles, and the teeth of the differential pinions do not move over the teeth of the differential side gears.

When the vehicle turns, one wheel must turn faster than the other. The differential side gear driving the outside wheel through the axle, will turn faster than the side gear of the inside wheel. For the drive ring gear to remain meshed with

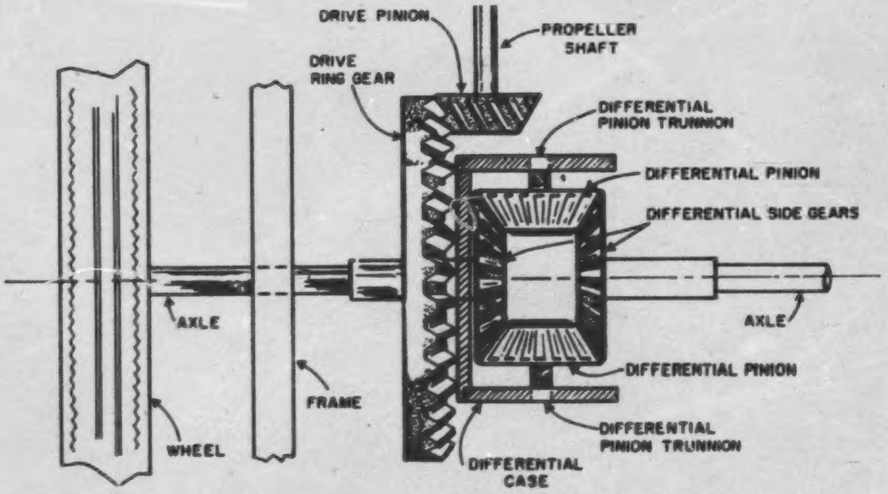

DRIVE PINION
PROPELLER SHAFT
DRIVE RING GEAR
DIFFERENTIAL PINION TRUNNION
DIFFERENTIAL PINION
DIFFERENTIAL SIDE GEARS
AXLE
AXLE
DIFFERENTIAL PINION
FRAME
WHEEL
DIFFERENTIAL PINION TRUNNION
DIFFERENTIAL CASE

Figure 10-32.—Rear axles and differential. 227.61

the two differential side gears, each turning at different speeds, the differential pinions must turn on their trunnions. The amount by which the differential pinions cause the inside side gear to slow in the rate of turn is the amount by which they will cause the outside side gear to increase the rate of turn. The average speed of the two side gears is always equal to the speed of the drive ring gear. For example, if the drive ring gear makes four revolutions and the inner side gear, axle, and wheel make one revolution, the outside wheel will rotate seven times.

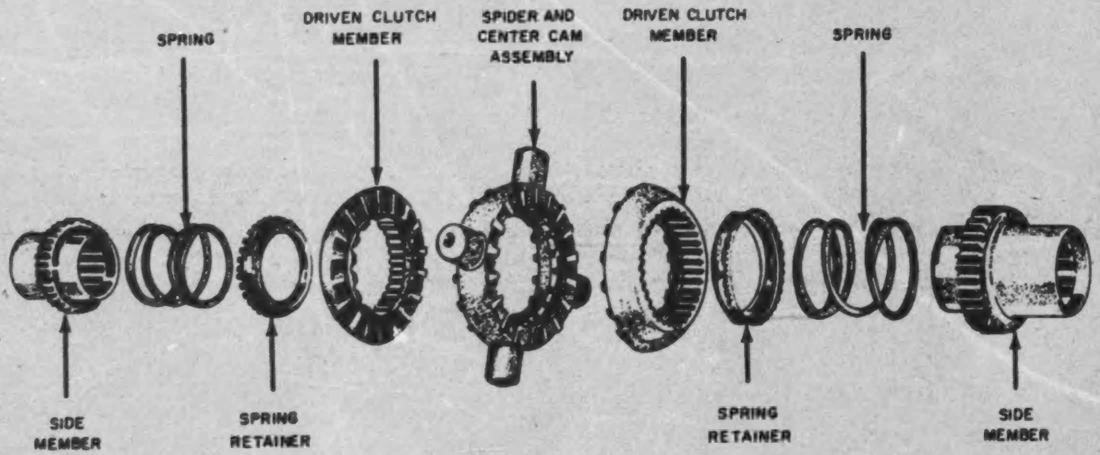
If one wheel spins free from traction on a vehicle using a conventional differential, the other wheel loses power because the differential pinions are revolving around the side gear of the stationary wheel and applying all the power to the spinning wheel. This result would be entirely unsatisfactory in towing tractors; therefore, a no-spin differential is employed.

NO-SPIN DIFFERENTIAL

To provide the means of improving tractive effort of the driving wheels when one wheel slips from loss of traction, the differential must prevent actual slippage and apply torque power to the driving wheels only to the extent that the wheels can utilize the torque without slipping. The no-slip differential (fig. 10-33) uses a pair of toothed clutches to do this. It does not contain side gears as does the conventional differential. Instead it contains a spider attached to the drive ring gear through four differential pinions turning on the spider trunnions, plus two driven clutch members with side teeth that are indexed by spring pressure with side teeth in the spider. Two side members are splined to the wheel axles and in turn are splined into the driven clutch members.

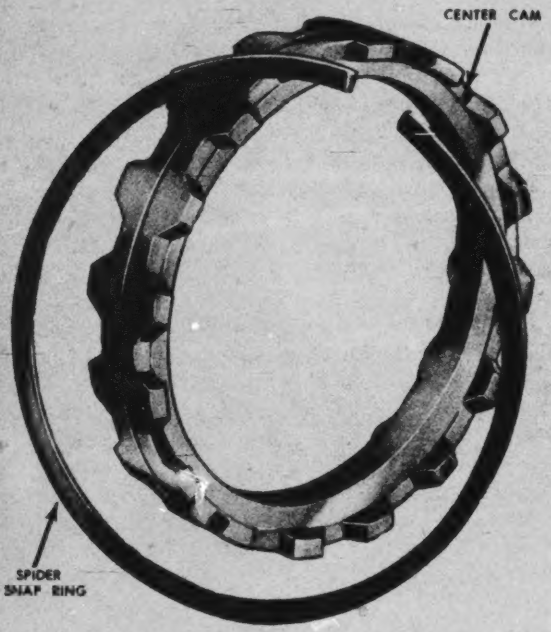
The center cam (fig. 10-34) in the spider is held in place by a snap-ring that permits the center cam to rotate but does not permit it to move laterally. When making a right turn, the right driven clutch member remains fully engaged with the spider clutch teeth (fig. 10-35).

The spider clutch teeth (the driving teeth) drive the right (inside) wheel at drive ring gear speed. The left wheel (outside) covers a greater distance and must turn faster than drive ring gear speed. The differential must permit this action. As the left wheel begins to turn faster, the left driven clutch member also turns faster than drive ring gear and spider speed. As the left driven clutch member begins to turn faster, the cam lobes or ramps on its edge ride up on the cam lobes on the center cam. This action pushes the left-driven clutch member away from the



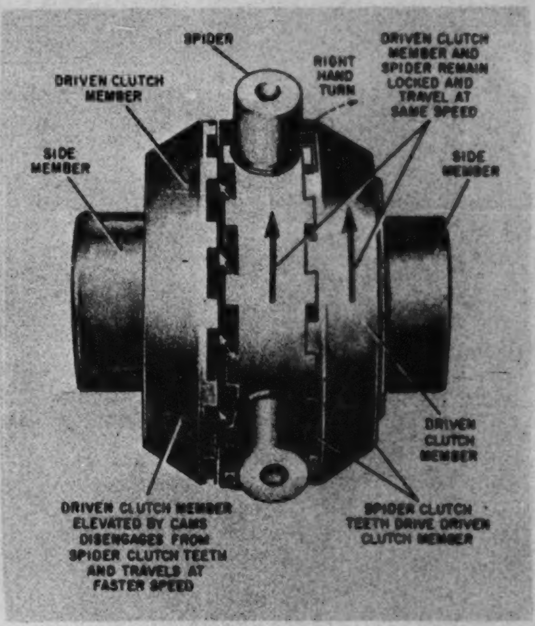
81.198

Figure 10-33.—No spin differential disassembled.


CENTER CAM
SPIDER SNAP RING

227.82

Figure 10-34.–Construction of center cam.


SPIDER
DRIVEN CLUTCH MEMBER
RIGHT HAND TURN
DRIVEN CLUTCH MEMBER AND SPIDER REMAIN LOCKED AND TRAVEL AT SAME SPEED
SIDE MEMBER
SIDE MEMBER
DRIVEN CLUTCH MEMBER
DRIVEN CLUTCH MEMBER ELEVATED BY CAMS DISENGAGES FROM SPIDER CLUTCH TEETH AND TRAVELS AT FASTER SPEED
SPIDER CLUTCH TEETH DRIVE DRIVEN CLUTCH MEMBER

227.63

Figure 10-35.–Operation of no-spin differential during a turn.

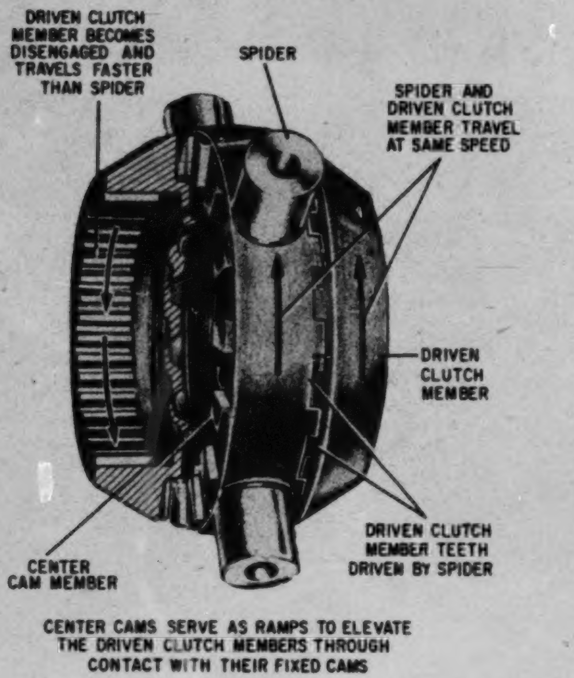
spider so the clutch teeth disengage. (See fig. 10-36.) As the crest of the ramp is passed, spring pressure forces the teeth of the driven clutch member back into full engagement with the teeth on the spider. This action is repeated as long as the left wheel turns more rapidly than the right wheel. Full drive is applied to the right wheel; no drive is applied to the left wheel. As soon as the vehicle completes the turn and the left wheel slows down to the right-wheel speed, driving power is applied equally to both. For a left turn the action is similar except that full drive is applied to the left wheel; the right wheel turns more rapidly than the left wheel.

With the no-spin differential one wheel cannot spin because of loss of traction and thereby deprive the other wheel of driving effort. For example, suppose that one wheel is on ice and the other wheel is on dry pavement. The wheel on ice is assumed to have no traction. The wheel on ice cannot spin because wheel speed is governed by the speed of the wheel applying tractive effort. Therefore, the wheel on dry pavement will pull to the limit of its tractional resistance at the pavement.

MAINTENANCE

The grease in the differential should be periodically checked and brought to the proper level if needed. The area under the differential should be checked after the vehicle has been parked to determine that the gaskets in the differential housing are not leaking. When found leaking, drain the grease, support the housing, remove the bolts and old gasket, clean the surfaces, and install a new gasket. When operating the vehicle in cold weather, the manufacturer's specifications should be consulted to determine the differential grease to be used. It may be necessary to change grease with the seasons.

The first clue to existing trouble in a differential is usually a noise. Defective universal joints, rough rear wheel bearings, or tire noises


DRIVEN CLUTCH MEMBER BECOMES DISENGAGED AND TRAVELS FASTER THAN SPIDER
SPIDER
SPIDER AND DRIVEN CLUTCH MEMBER TRAVEL AT SAME SPEED
DRIVEN CLUTCH MEMBER
DRIVEN CLUTCH MEMBER TEETH DRIVEN BY SPIDER
CENTER CAM MEMBER
CENTER CAMS SERVE AS RAMPS TO ELEVATE THE DRIVEN CLUTCH MEMBERS THROUGH CONTACT WITH THEIR FIXED CAMS

227.64

Figure 10-36.—Action of center cam during a turn.

may be improperly diagnosed as differential trouble. To properly determine the trouble, the source of the noise must be determined and the operating conditions under which the noise is most pronounced. A clue may be gained as to the cause of the trouble by noting whether the noise is a growl, a hum, or a knock; whether it is heard when the vehicle is operating on a straight road, or on turns only; and whether the noise is most noticeable when the engine is driving the vehicle or when it is coasting.

A humming noise in the differential usually means that the drive ring gear or drive pinion needs adjusting. An improperly adjusted ring gear or pinion prevents normal tooth contact between the gears and produces gear noise and wear. The humming noise will gradually take on a growling characteristic if the trouble is not corrected, and the ring gear and pinion will eventually need replacing. The manufacturer's specifications and instructions should be consulted, studied, and followed for any adjustment.

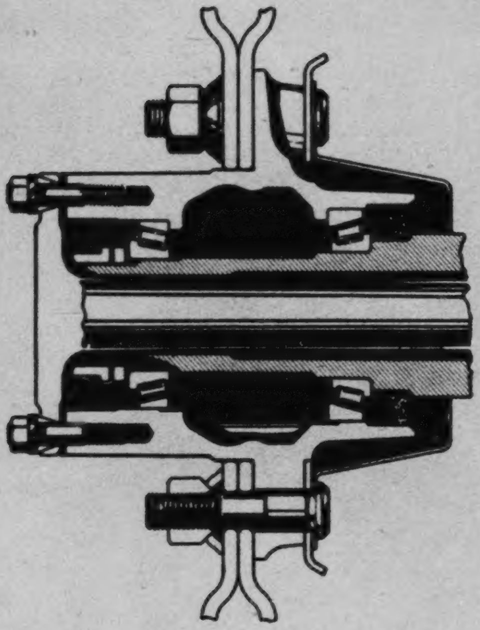
Tire noises may be mistaken for differential noises. Tire noises vary according to the type of pavement the tires are on while differential noise will not. To determine whether the noise is caused by tire or differential, drive the vehicle over several types of pavement. If the noise changes with the type of pavement, tires are the cause.

A noise that is present in the differential only when the vehicle is rounding a corner is usually caused by trouble in the differential case assembly. The differential pinion gears may be too tight on their trunnions, or the differential side gears may be tight. Damaged or worn gears can produce a noise when the vehicle turns. If bearings or gears are damaged, a knocking noise can result.

DRIVE AXLE ASSEMBLIES

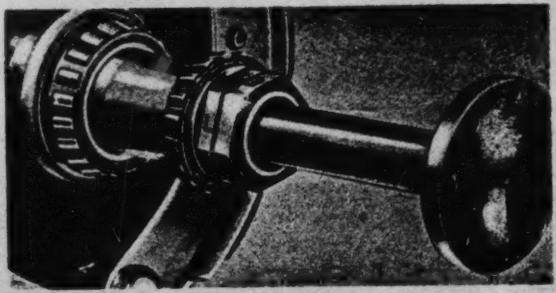
The drive axle conveys the torque power from the differential to the wheel. It is made of steel and is solid in construction. Most aviation support equipment has full-floating drive axles (fig. 10-37). The wheel fits over the end of the axle housing, and the weight is carried by two roller bearings between the wheel and the axle housing. The outer end of the axle has a flange that bolts to the wheel. Thus the axle goes through the axle housing and wheel and applies turning power to the outside of the wheel. The wheel is held on the axle housing by adjustment nuts (fig. 10-38). The wheel hub, roller bearings, and axle shaft are lubricated by the same grease that lubricates the differential. The axle can be removed by removing the flange bolts, breaking the flange seal, and pulling the axle from the housing. This can be done without removing the wheel. When replacing an axle, the proper size and thickness of gasket should be used as specified in the manufacturer's instructions.

Some aviation support equipments, such as tow tractors, have rear axle planetary gears at the wheel end of the axle. These gears further reduce the power between the axle and the



227.65
Figure 10-37.—Cross section of rear hub in full floating axle.

wheel. The axle has a gear on the outer end which turns three planetary pinion gears; these turn an internal ring gear bolted to the wheel. This system is all lubricated by the same grease that lubricates the differential. For adjustment and servicing consult the manufacturer's instructions.



227.66
Figure 10-38.—Bearing mounting and adjustment nuts of full-floating construction.

SAFETY

While clutches, transmissions, propeller shaft assemblies, differentials, or rear axle assemblies are not usually dangerous to work on or service, all safety precautions related to mechanical work must be followed by every ASM to prevent injury. These assemblies are heavy when removed as units, and the simple dropping of one of them can cause a broken foot.

In addition to the usual safety precautions, it should be reemphasized that proper blocking of the vehicle being worked on is always a safe practice.

In addition, when one end of a vehicle is raised from the ground, a minimum of two safety stands should be used in place of the jack or lifting device that was used to raise the vehicle. It is never a safe practice to be under a vehicle when it is held off the ground only by lifting devices.

CHAPTER 11

HARDWARE, FUELS, LUBRICANTS, AND HYDRAULIC FLUIDS

Hardware and petroleum products have always been important to modern military operations. These products are no less important to the ASM. This chapter covers these products as related to aviation support equipment.

HARDWARE

Because of the small size of most hardware items, such as seals, packings, bolts, safety wire, and other hardware, their importance is often overlooked. However, the safe and efficient operation of any ground support equipment is greatly dependent upon correct selection and use of this hardware.

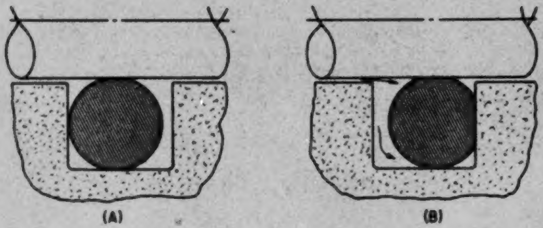
SEALS

Seals are used throughout the systems of ground support equipment to minimize leakage of fluids and gases. Seals may be made up of packings or gaskets. Packings are usually in the shape of O-rings or other shapes for use on sliding or moving assemblies, and gaskets are seals between nonmoving fittings and bosses on support equipment.

O-rings

Most O-rings used in support equipment installations are made of synthetic rubber. They are used in units that contain moving parts, such as actuating cylinders, selector valves, etc.

The O-ring packing seals effectively in both directions. This sealing is accomplished by distortion of its elastic compound. Figure 11-1 (A) shows an O-ring of the proper size installed in a grooved seat. Notice that the clearance for the O-ring is less than its free outer diameter. The cross section of the O-ring is squeezed out of round prior to the application of pressure. In this manner, contact is ensured with the inner and outer walls of the passage under static (no pressure) conditions.

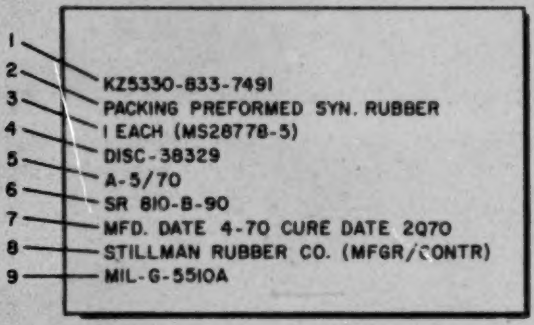


194.71
Figure 11-1.—O-rings properly installed.

Figure 11-1(B) shows the action of the O-ring when pressure is applied. It should also be noted, in figure 11-1, that backup rings are not installed. In hydraulic systems where components are subjected to 1,500 psi and below, AN6227, AN6230, and MS28775 packings are used. In such installations, backup rings are not required although desirable. In systems with pressures up to 3,000 psi, backup rings are used in conjunction with the packings.

O-ring Identification

O-rings are manufactured according to Military Specifications and can be best identified from the technical information printed on the O-ring package. (See fig. 11-2.) The size cannot be positively identified by visual examination without the use of special equipment. For this


1
2
3
4
5
6
7
8
9
KZ5330-833-7491
PACKING PREFORMED SYN. RUBBER
I EACH (MS28778-5)
DISC-38329
A-5/70
SR 810-B-90
MFD. DATE 4-70 CURE DATE 2Q70
STILLMAN RUBBER CO. (MFGR/CONTR)
MIL-G-5510A

1. Stock number.
2. Nomenclature.
3. Part number.
4. Contract number.
5. Preservation.
6. Rubber composition number.
7. Date of manufacture and cure date.
8. Manufacturer.
9. Military specification number.

194.72

Figure 11-2.—O-ring package identification.

reason, O-rings are made available in individual hermetically sealed envelopes labeled with all the necessary data. It is recommended that they be procured and stored in these envelopes.

NOTE: Colored dots, dashes, and stripes or combinations of dots and dashes on the surface of the O-ring are no longer used for identification of this type seal.

Figure 11-2 shows the information printed on the O-ring packages, essential to determine the intended use, qualifications, and age limitations. The manufacturer's cure date is one of the more important printed items listed on the package. This cure date is denoted in quarters. For example, the cure date 2Q71 indicates that the O-ring was manufactured during the second quarter of 1971. Synthetic rubber parts manufactured during any given quarter are not considered one quarter old until the end of the succeeding quarter. Most O-ring age limitation is determined by this cure date, anticipated service life, and replacement schedule.

Age limitation of synthetic rubber O-rings is based on the fact that the material deteriorates with age. O-ring age is computed from the cure date. The term cure date is used in conjunction with replacement kits which contain O-rings, parts, and hardware for shop repair of various components. O-ring cure dates also provide the bases for O-ring replacement schedules, which are determined by O-ring service life. The service life (estimated time of trouble-free service) of O-rings also depends upon such conditions as use, exposure to certain elements, both natural and imposed, and subjection to physical stress. Operational conditions imposed on O-rings in one component may necessitate O-ring replacement more frequently than replacement of identical O-rings in other components. Therefore, it is necessary to adhere to the recommended replacement schedule for each individual component. The age of O-rings in a spare part is determined from the assembly date recorded on the service or identification plate and/or on the exterior of the container. All O-rings over 24 months old should be replaced or, if nearing their age limit (24 months), should not be used for replacement.

O-ring Storage

Proper storage practices must be observed to prevent deformation and deterioration of rubber O-rings. Most synthetic rubbers are not damaged by several years of storage under ideal conditions. However, most synthetic rubbers deteriorate when exposed to heat, light, oil, grease, fuels, solvents, thinners, moisture, strong drafts, or ozone (form of oxygen formed from electrical discharge). Damage by exposure is magnified when rubber is under tension, compression, or stress. There are several conditions to be avoided, including the following:

1. Deformation as a result of improper stacking of parts and storage containers.
2. Creasing caused by a force applied to corners and edges, and by squeezing between boxes and storage containers.
3. Compression and flattening, as a result of storage under heavy parts.
4. Punctures caused by staples used to attach identification.
5. Deformation and contamination due to hanging the O-rings from nails or pegs. O-rings should be kept in their original envelopes, which provide preservation, protection, identification, and cure date.

6. Contamination by piercing the sealed envelopes to store O-rings on rods, nails, or wire handling devices.

7. Contamination by fluids leaking from parts stored above and adjacent to O-ring surfaces.

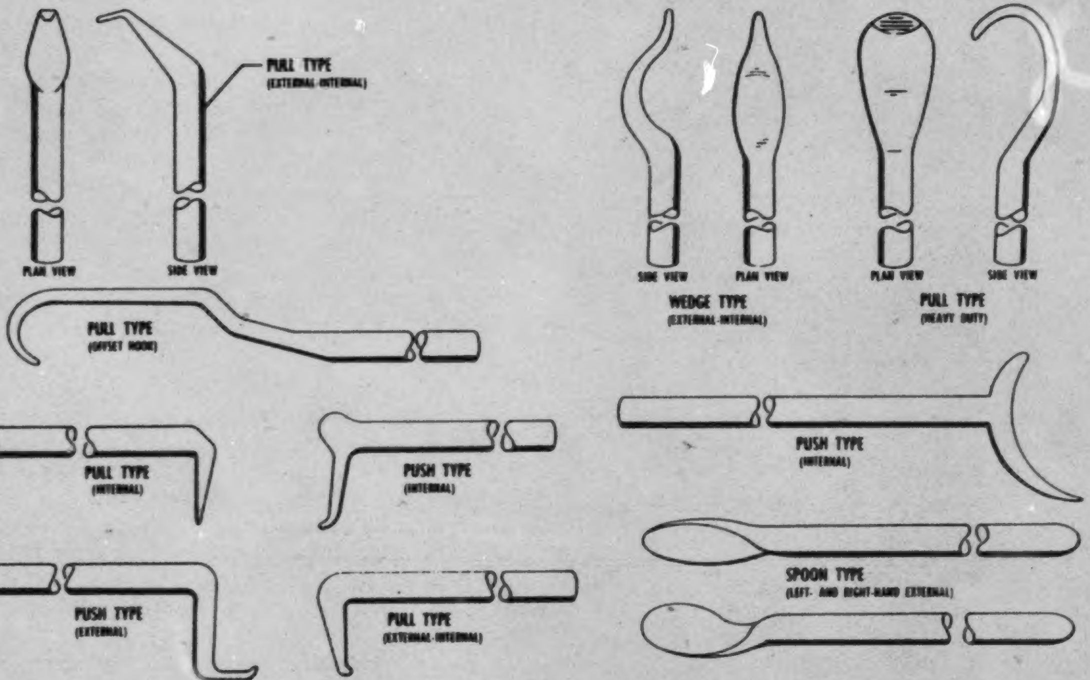
8. Contamination caused by adhesive tapes applied directly to O-ring surfaces. A torn O-ring package should be secured with a pressure-sensitive, moisture-proof tape, but the tape must not contact the O-ring surfaces.

9. Retention of overage parts as a result of improper storage arrangement or illegible identification. O-rings should be arranged so the older seals are used first.

O-ring Removal and Installation

The successful operation of a hydraulic system and the units within depends greatly upon the methods and procedures used in handling and installing hydraulic seals. These seals are comparatively soft and should not be subjected to any nicks, scratches, or dents. They should be kept free of dirt and foreign matter and should not be exposed to extreme weather conditions. When hydraulic seals are chosen for installation, they should not be picked up with sharp instruments, and the preservative should not be removed until they are ready for installation.

During the installation or removal of hydraulic seals, as well as other tasks, an ASM's best friend is the correct tool. A variety of these tools may be used on any given job. Suggestions for fabricating typical tools for use in replacing and installing O-rings and backup rings are shown in figure 11-3. These tools should be fabricated from soft metal such as brass and aluminum; however, tools made from phenolic rod, plastics, and wood may also be used.


PULL TYPE
(EXTERNAL-INTERNAL)
PLAN VIEW
SIDE VIEW
PULL TYPE
(OFFSET HOOK)
PULL TYPE
(INTERNAL)
PUSH TYPE
(INTERNAL)
PUSH TYPE
(EXTERNAL)
PULL TYPE
(EXTERNAL-INTERNAL)
SIDE VIEW
PLAN VIEW
WEDGE TYPE
(EXTERNAL-INTERNAL)
PLAN VIEW
SIDE VIEW
PULL TYPE
(HEAVY DUTY)
PUSH TYPE
(INTERNAL)
SPOON TYPE
(LEFT- AND RIGHT-HAND EXTERNAL)

215.12

Figure 11-3.—Typical O-ring installation and removal tools.

When removing or installing O-rings, avoid using pointed or sharp-edged tools which might cause scratching or marring of hydraulic component surfaces or cause damage to the O-rings. While using the seal removal and installation tools, contact with cylinder walls, piston heads, and related precision components is not desirable. With practice, the ASM should become proficient in using these tools.

Notice in figure 11-4(A) how the hook-type removal tool is positioned under the O-ring and then lifted to allow the extractor tools, as well as the removal tools, to pull the O-ring from its cavity. View (B) shows the use of another type of extractor tool in the removal of internally installed O-rings.

In view (C), notice the extractor tool positioned under both O-rings at the same time. This method of manipulating the tool positions both O-rings, allowing the hook-type removal tool to extract both O-rings with minimum effort. View (D) shows practically the same removal as view (C), except for the use of a different type of extractor tool.

The removal of external O-rings is less difficult than the removal of internally installed O-rings. Views (E) and (F) illustrate two accepted removal methods. View (E) shows the use of a spoon-type extractor, which is positioned under the seal. After the O-ring is dislodged from its cavity, the spoon is held stationary while simultaneously rotating and withdrawing the piston. View (F) installation is similar to view (E), except only one O-ring is installed, and a different type of extractor tool is used. The wedge-type extractor tool is inserted beneath the O-ring; the hook-type removal tool hooks the O-ring. A slight pull on the latter tool removes the O-ring from its cavity.

After the removal of all O-rings, cleaning of the affected parts which will receive new O-rings is mandatory. Ensure that the area used for such installations is clean and free from all contamination. Each O-ring to be replaced should be removed from its sealed package and inspected for defects such as blemishes, abrasions, cuts, or punctures. Although an O-ring may appear perfect at first glance, slight surface flaws may exist. These are often capable of preventing satisfactory O-ring performance under the variable operating pressures of hydraulic systems. O-rings should be rejected for flaws that will affect their performance.

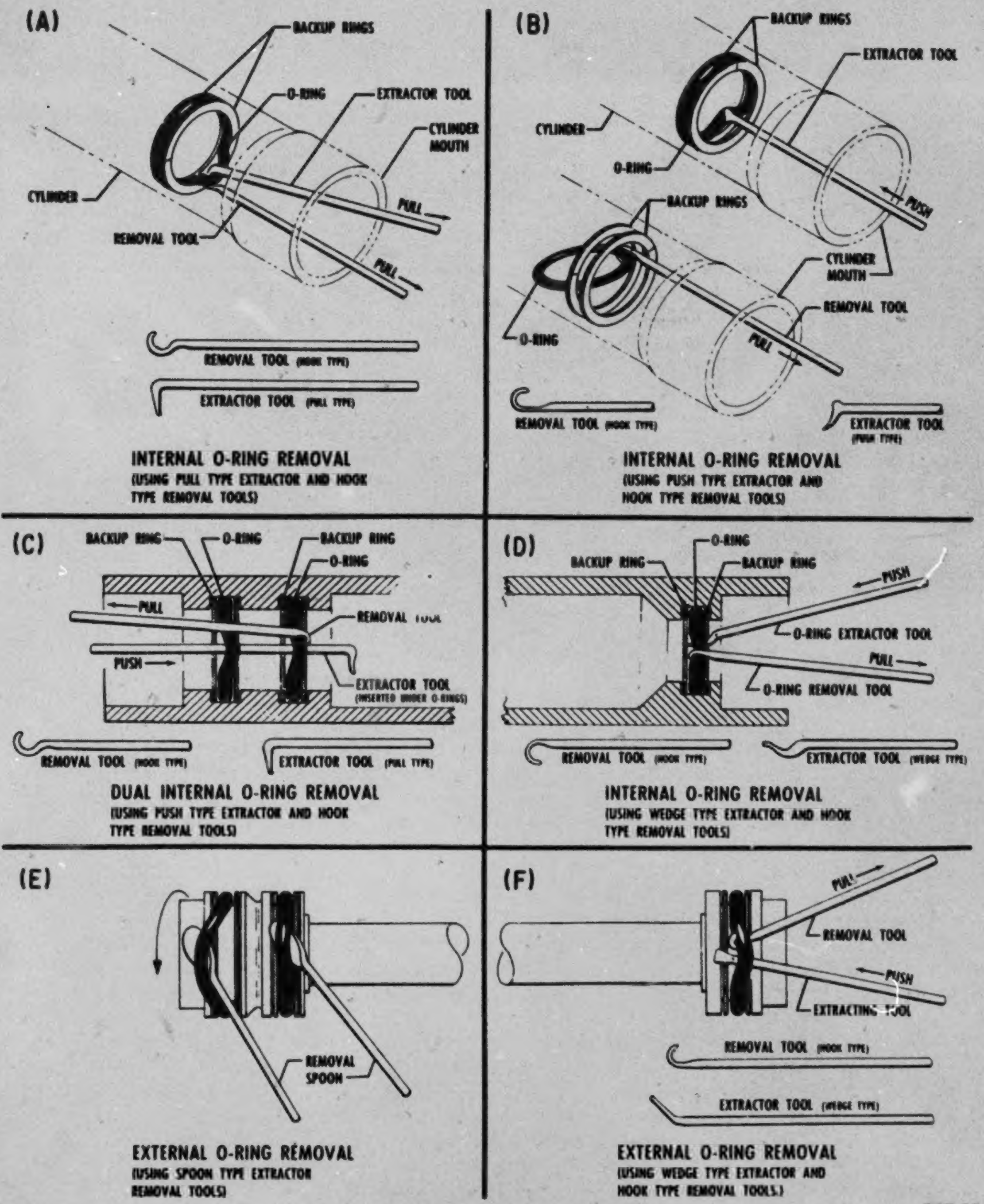
By rolling the ring on an inspection cone or dowel, the inner diameter surface can also be checked for small cracks, particles of foreign matter, and other irregularities that would cause leakage or shorten the life of O-rings. The slight stretching of the ring when it is rolled inside out will help to reveal some defects not otherwise visible.

A further check of each O-ring should be made by stretching it between the fingers, but care must be taken not to exceed the elastic limits of the rubber. Following these inspection procedures will prove to be a maintenance economy. It is far more desirable to take care when identifying and inspecting O-rings than to repeatedly repair components because of faulty seals.

After inspection and prior to installation, immerse the O-ring in clean hydraulic fluid of the type which is compatible with the seal. During the installation, avoid rolling and twisting the O-ring to maneuver it into place. If possible, keep the position of the O-ring's mold line constant. When the O-ring installation requires spanning or inserting through sharp threaded areas, ridges, slots, and edges, use protective measures, such as O-ring entering sleeves as shown in figure 11-5(A). If the recommended O-ring entering sleeve (soft thin-wall metallic sleeve) is not available, paper sleeves and covers may be fabricated by using the seal package (gloss side out) or lint-free bond paper. (See fig. 11-5(B) and (C).)

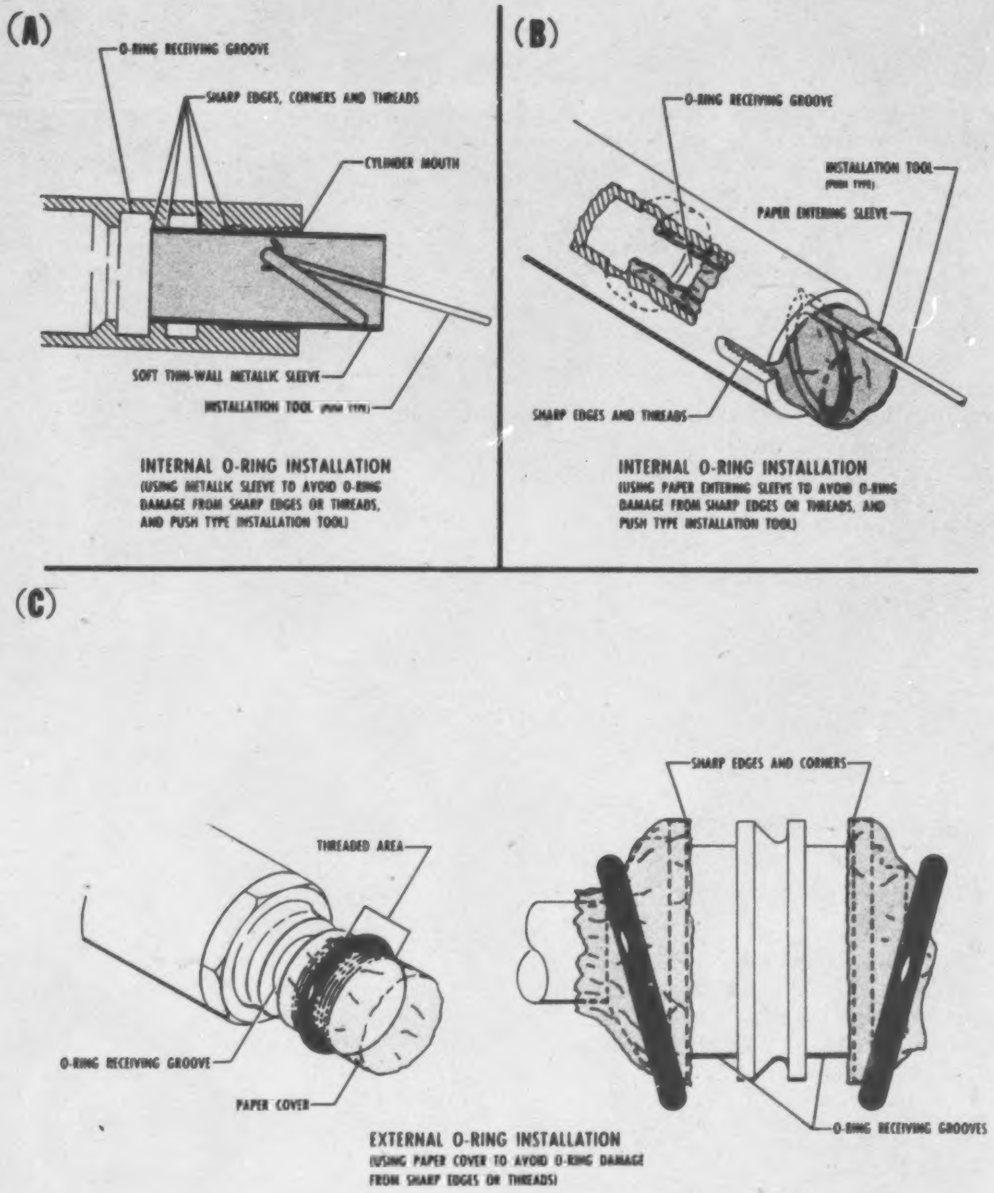
Adhesive tapes should not be used to cover danger areas on components. Gummy substances left by the adhesives are extremely detrimental to hydraulic systems.

After the O-ring is placed in the cavity provided, gently roll the O-ring with the fingers to remove any twist that might have occurred during installation.


(A)
BACKUP RINGS
O-RING
EXTRACTOR TOOL
CYLINDER MOUTH
CYLINDER
REMOVAL TOOL
PULL
PULL
REMOVAL TOOL (HOOK TYPE)
EXTRACTOR TOOL (PULL TYPE)
INTERNAL O-RING REMOVAL
(USING PULL TYPE EXTRACTOR AND HOOK TYPE REMOVAL TOOLS)
(B)
BACKUP RINGS
EXTRACTOR TOOL
CYLINDER
O-RING
PUSH
BACKUP RINGS
CYLINDER MOUTH
REMOVAL TOOL
O-RING
PULL
REMOVAL TOOL (HOOK TYPE)
EXTRACTOR TOOL (PUSH TYPE)
INTERNAL O-RING REMOVAL
(USING PUSH TYPE EXTRACTOR AND HOOK TYPE REMOVAL TOOLS)
(C)
BACKUP RING
O-RING
BACKUP RING
O-RING
PULL
REMOVAL TOOL
PUSH
EXTRACTOR TOOL (INSERTED UNDER O-RINGS)
REMOVAL TOOL (HOOK TYPE)
EXTRACTOR TOOL (PULL TYPE)
DUAL INTERNAL O-RING REMOVAL
(USING PUSH TYPE EXTRACTOR AND HOOK TYPE REMOVAL TOOLS)
(D)
O-RING
BACKUP RING
BACKUP RING
PUSH
O-RING EXTRACTOR TOOL
PULL
O-RING REMOVAL TOOL
REMOVAL TOOL (HOOK TYPE)
EXTRACTOR TOOL (WEDGE TYPE)
INTERNAL O-RING REMOVAL
(USING WEDGE TYPE EXTRACTOR AND HOOK TYPE REMOVAL TOOLS)
(E)
REMOVAL SPOON
EXTERNAL O-RING REMOVAL
(USING SPOON TYPE EXTRACTOR REMOVAL TOOLS)
(F)
PULL
REMOVAL TOOL
PUSH
EXTRACTING TOOL
REMOVAL TOOL (HOOK TYPE)
EXTRACTOR TOOL (WEDGE TYPE)
EXTERNAL O-RING REMOVAL
(USING WEDGE TYPE EXTRACTOR AND HOOK TYPE REMOVAL TOOLS.)

215.13

Figure 11-4.—O-ring removal.


(A)
O-RING RECEIVING GROOVE
SHARP EDGES, CORNERS AND THREADS
CYLINDER MOUTH
SOFT THIN-WALL METALLIC SLEEVE
INSTALLATION TOOL (PUSH TYPE)
(B)
O-RING RECEIVING GROOVE
INSTALLATION TOOL (PUSH TYPE)
PAPER ENTERING SLEEVE
SHARP EDGES AND THREADS
(C)
THREADED AREA
O-RING RECEIVING GROOVE
PAPER COVER
SHARP EDGES AND CORNERS
O-RING RECEIVING GROOVES

INTERNAL O-RING INSTALLATION
(USING METALLIC SLEEVE TO AVOID O-RING DAMAGE FROM SHARP EDGES OR THREADS, AND PUSH TYPE INSTALLATION TOOL)

INTERNAL O-RING INSTALLATION
(USING PAPER ENTERING SLEEVE TO AVOID O-RING DAMAGE FROM SHARP EDGES OR THREADS, AND PUSH TYPE INSTALLATION TOOL)

EXTERNAL O-RING INSTALLATION
(USING PAPER COVER TO AVOID O-RING DAMAGE FROM SHARP EDGES OR THREADS)

215.14

Figure 11-5.—O-ring installation.

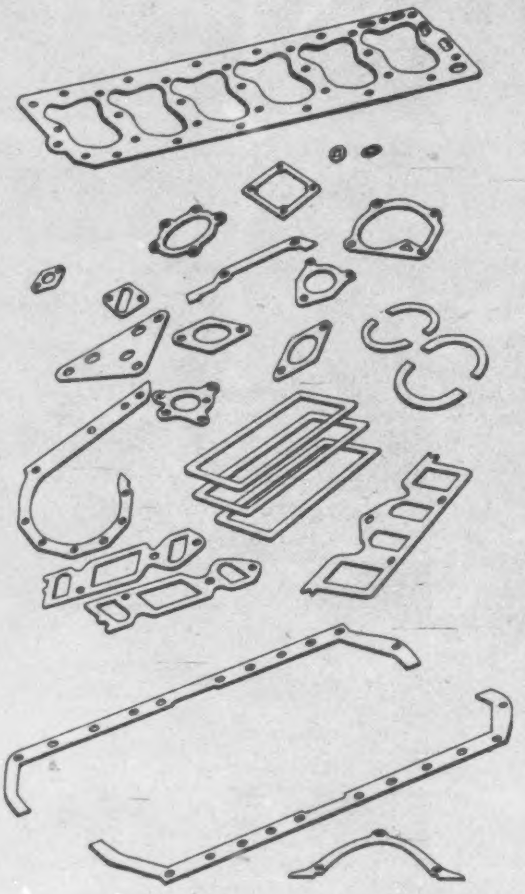
GASKETS

Gaskets are used as static or stationary seals. Their principal use in a fluid system is around end caps of cylinders, valves, and other units. Gaskets must not be compressed against irregular or rough surfaces that could cut or damage them. To do so can destroy the sealing quality of the gasket. Since it is not possible to have the matching surfaces of the cylinder block and cylinder head of an engine smooth enough to make a gastight fit, a gasket is used that is able to withstand the pressure and heat developed by the cylinders. The gaskets (fig. 11-6) that serve as seals between engine parts in assembly require as much attention during assembly as any other part. It is impractical to machine all surfaces so that they fit together to form a perfect seal. The gaskets make a joint that is air, water, or oil tight; therefore, when properly installed, they prevent loss of compression, coolant, or lubricant.

The CYLINDER HEAD GASKET is placed between the cylinder head and engine block to maintain a gas- and coolant-tight seal. These gaskets may be metal sheets soft enough to deform as required, but they are usually made in the form of two thin plates of soft metal with asbestos filling between them. Holes are punched in the gasket to conform with the openings in the head and block, which allows the cooling water to circulate. If a poorly made or improper gasket is used, the flow of cooling water may be restricted, causing troublesome hot spots.

On some engines, especially V-type, the gaskets are so nearly uniform that they can be turned upside down or end for end and still fit the retaining studs and combustion chambers. If they are improperly installed, however, they will stop water circulation at some parts of the engine. It is important to make sure that the correct gasket is used and that it is correctly installed.

The INTAKE AND EXHAUST MANIFOLD GASKETS are usually made from asbestos formed to the desired shape. Some of them are metal covered asbestos similar in construction to a head gasket. Because of the heat of the exhaust and intake air, it is necessary that manifold gaskets be made from a material that will not burn.



81.52

Figure 11-6.—Engine overhaul gasket kit.

The OIL PAN GASKET is generally made from pressed cork. It may be made in one piece but more often it is made in two pieces: one piece for each side of the pan. Each end of the pan is sealed with cork or neoprene gasket material.

The other gaskets for an engine are usually cut from pressed paper that is oil resistant. The thickness of the paper varies in accordance with manufacturer's recommendations. Often the gaskets used will create specified clearances between moving parts of an engine.

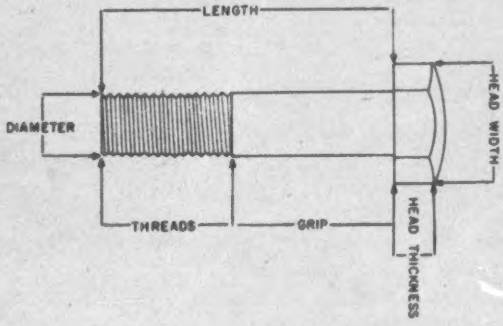
When installing any gasket in an engine, it is important that the surfaces to be sealed be clean and free from grit and parts of the old gasket. A putty knife is useful for cleaning gasket surfaces. You must be sure the gasket is in the proper position and does not slip when the two parts are brought together. Heavy grease or a gasket compound will help you make sure the gaskets stay in place and form a good seal.

The ASM should refer to *FLUID POWER*, NAVPERS 16193 (Series) and the latest applicable maintenance manual for further references to seals and gaskets.

BOLTS

Many types of bolts are used on support equipment, and each type is used to fasten something in place. However, before discussing some of these types, it might be helpful at this point to list and explain some commonly used bolt terms. The ASM should know the names of bolt parts. He should also be aware of the bolt dimensions that must be considered in selecting a bolt. Figure 11-7 illustrates both types of information.

The three principal parts of a bolt are the HEAD, THREAD, and GRIP. It is possible that two of these parts are well known, but perhaps the "grip" is an unfamiliar term. If so, notice that the grip is the unthreaded part of the bolt shaft and that it extends from the threads to the bolthead. The head is the larger diameter of the bolt and may be one of many shapes or designs. The head retains the bolt in place in one direction, and the nut used on the threads retains it in the other direction.

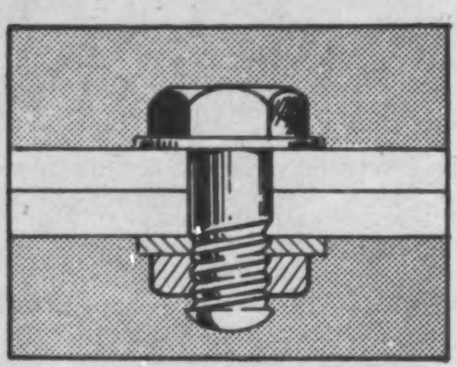


217.65
Figure 11-7.—Bolt terms and dimensions.

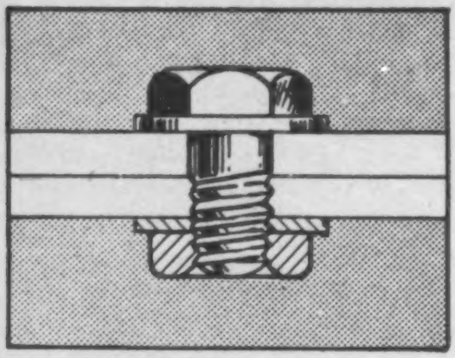
In order to choose the correct replacement for an unserviceable bolt, several bolt dimensions must be considered, one being the length of the bolt. As shown in figure 11-7, the bolt length is the distance from the tip of the threaded end to the head of the bolt. Correct length selection is indicated when the chosen bolt extends through the nut at least 1/32 inch in the case of flat-end bolts (fig. 11-7) or in the case of chamfered (rounded) end bolts, at least one full chamfer should extend through the nut. If the bolt is too short, it may not extend out of the bolthole far enough for the nut to be securely fastened. If it is too long, it may extend so far that it interferes with the movement of nearby parts. Unnecessarily long bolts, especially in numbers, can affect weight and balance and reduce the payload capacity.

In addition, if a bolt is too long or too short, its grip will usually be the wrong length. As shown in figure 11-8, grip length should be approximately the same as the thickness of the material to be fastened. If the grip is too short, the threads of the bolt will extend into the bolthole and may act like a reamer when the material is vibrating. To prevent this, make certain that no more than two threads extend into the bolthole. Also make certain that any threads that enter the bolthole extend only into the thicker member that is being fastened. If the grip is too long, the nut will run out of threads before it can be tightened. In this event a bolt with a shorter grip should be used, or if the bolt grip extends only a short distance through the hole, a washer may be used.

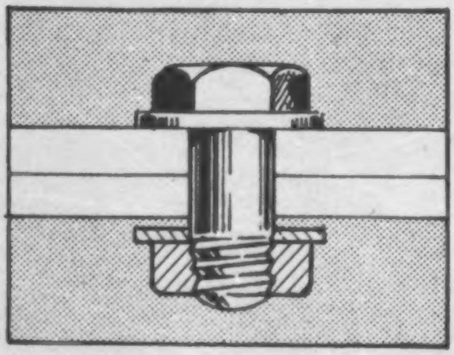
A second bolt dimension that must be considered is diameter. As shown in figure 11-7 the diameter of the bolt is the thickness of its shaft. If this thickness is 1/4 inch or more, the bolt diameter is usually given in such fractions of an inch as 1/4, 5/16, 7/16, 1/2, and the like. However, if the bolt is less than 1/4 inch thick, the diameter is usually expressed as a whole



BOLT GRIP LENGTH CORRECT



BOLT GRIP LENGTH TOO SHORT



BOLT GRIP LENGTH TOO LONG

217.66

Figure 11-8.—Correct and incorrect grip lengths.

number. For instance, a bolt that is 0.190 inch in diameter is called a No. 10 bolt, while a bolt that is 0.164 inch in diameter is called a No. 8.

The results of using a wrong-diameter bolt should be obvious. If the bolt is too big, it cannot of course enter the bolthole. If the diameter is too small, the bolt has too much play in the bolthole, and the chances are that it is not as strong as the correct size of bolt.

The third and forth bolt dimensions that should be considered when choosing a bolt replacement are head thickness and width. If the head is too thin or too narrow, it may not be strong enough to bear the load imposed on it. If the head is too thick or too wide, it may extend so far that it interferes with the movement of adjacent equipment components.

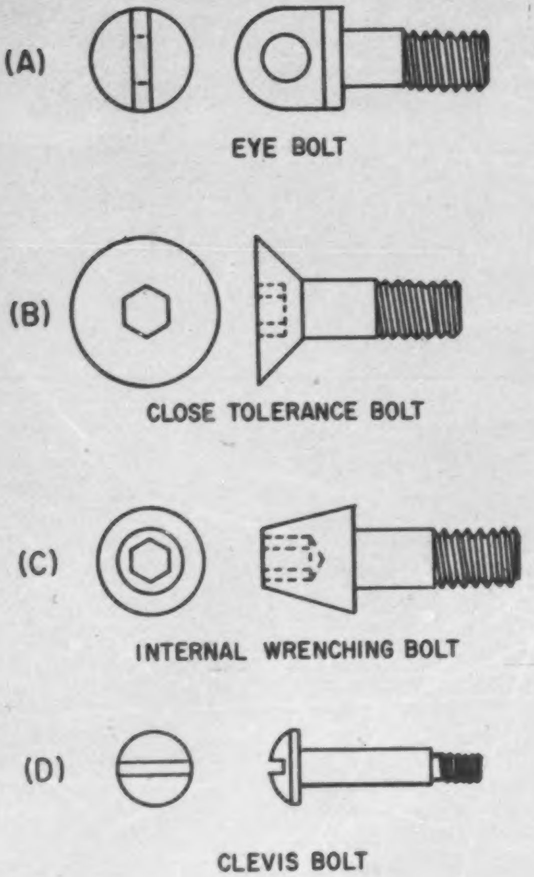
Boltheads

The most common type of head is the hex head, shown in figure 11-7. This type of head may be thick for greater strength or relatively thin in order to fit in places having limited clearances. In addition, the head may be common or drilled. A hex head bolt may have a single hole drilled through it between two of the sides of the hexagon and still be classed as a common. The drilled head hex bolt has three holes drilled in the head, connecting opposite sides of the hex.

Four additional types of boltheads are shown in figure 11-9. Notice that panel A shows an eyebolt, often used in mechanical control systems. Panel B shows a countersunk head, close tolerance bolt. Panel C shows an internal wrenching bolt. Both the countersunk head bolt and the internal wrenching bolts have hexagonal recesses (six-sided holes) in their heads. They are tightened and loosened by use of appropriate size Allen wrenches. Panel D shows a clevis bolt with its characteristic round head. This head may be slotted, as shown, to receive a common screwdriver or recessed to receive a Reed and Prince or a Phillips screwdriver.

Bolt Threads

Another structural feature in which bolts may differ is threads. These usually come in one



217.67

Figure 11-9.—Boltheads.

of the two types—coarse or fine, and the two are not interchangeable. For any given size of bolt there are a different number of coarse and fine threads per inch. For instance, consider the 1/4-inch bolts. Some are called 1/4-28 bolts, because they have 28 fine threads per inch. Others have only 20 coarse threads per inch and are called 1/4-20 bolts. To force one size of threads into another size, even though both are 1/4 inch, will strip the finer threads or softer metal. The same thing is true concerning the other sizes of bolts; therefore, make certain that bolts selected have the correct type of threads.

Bolt Material

The type of metal used in a bolt helps to determine its strength and its resistance to corrosion. Therefore, make certain that material is considered in the selection of replacement bolts. Some bolts have distinctive head markings that help to identify the material from which they are manufactured. In certain cases, manufacturers are compelled to make bolts of different dimensions or greater strength than the standard types. Such bolts are made for a particular application, and it is of extreme importance that like bolts are used in replacement. Such special bolts are usually identified by the letter S stamped on the head. Figure 11-10 shows the tops of several hex-bolt heads, each marked to indicate the type of bolt material.

Unless current directives specify otherwise, every unserviceable bolt should be replaced with a bolt of the same type. Of course, substitute and interchangeable items are sometimes available, but the ideal fix is a bolt-for-bolt replacement. The part number of a needed bolt may be obtained by referring to the Illustrated Parts Breakdown (IPB) for the equipment concerned.

Safety Wire

Safety wire is available in many different types and sizes. One must first select the correct type and size wire for the particular job. Many of the nuts, except the self-locking types, and boltheads on support equipment must be safetied, the method used depending upon the particular installation. Figure 11-11 illustrates the correct methods of installing safety wire. The following general rules apply to safety wiring:

1. All safety wire must be tight after installation, but not under so much tension that normal handling or vibration will break the wire.
2. The wire must be applied so that all pull exerted by the wire tends to tighten the nut or bolt.
3. Twists should be tight and even and the wire between nuts as taut as possible without overtwisting. Wire-twister pliers should be used

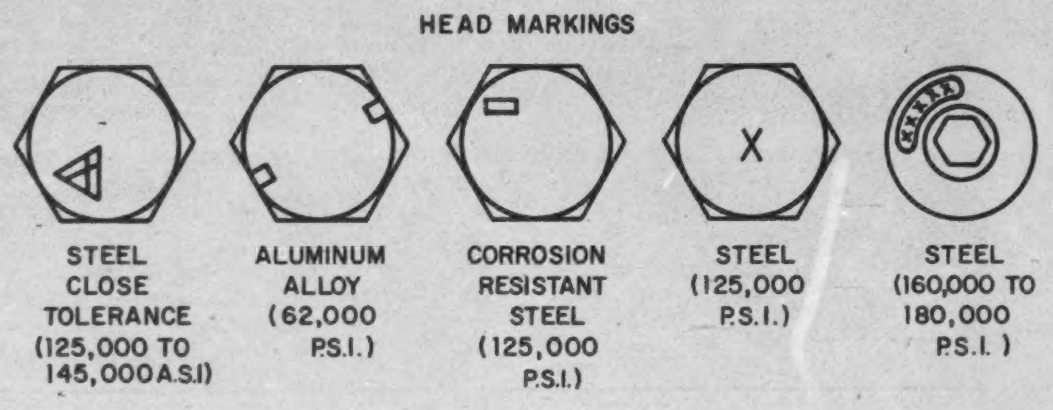
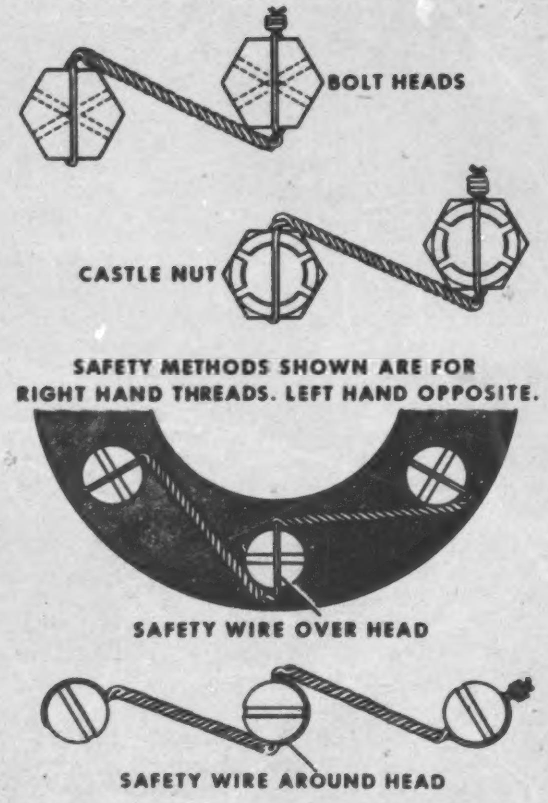

HEAD MARKINGS
STEEL CLOSE TOLERANCE (125,000 TO 145,000A.S.I)
ALUMINUM ALLOY (62,000 P.S.I.)
CORROSION RESISTANT STEEL (125,000 P.S.I.)
STEEL (125,000 P.S.I.)
STEEL (160,000 TO 180,000 P.S.I.)

Figure 11-10.—Bolthead markings. 217.68


BOLT HEADS
CASTLE NUT
SAFETY METHODS SHOWN ARE FOR RIGHT HAND THREADS. LEFT HAND OPPOSITE.
SAFETY WIRE OVER HEAD
SAFETY WIRE AROUND HEAD

217.81

Figure 11-11.—Safety wire installation.

if available; otherwise, wire between nuts should be twisted with the hands. The use of regular pliers will damage the wire. Regular pliers may be used only for final end twist prior to cutting off the excess wire.

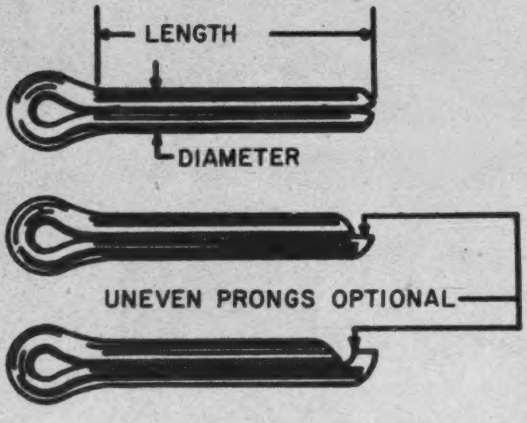
MISCELLANEOUS HARDWARE

The ASM should become familiar with other miscellaneous hardware for ground support equipment. He should be aware of their purpose in performing the proper maintenance of ground support equipment.

Cotter Pins

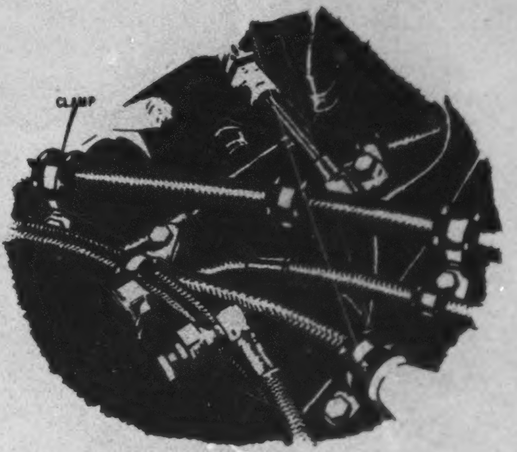
Cotter pins are used to secure bolts, screws, nuts, and pins. Some cotter pins are made of low-carbon steel, while others consist of stainless steel and thus are more resistant to corrosion. In addition, stainless steel cotter pins may be used in locations where nonmagnetic material is required. Regardless of shape or material, all cotter pins are used for the same general purpose—safetying. Figure 11-12 shows three types of cotter pins and how their size is determined.

NOTE: Whenever uneven prong cotter pins are used, the length measurement is to the end of the shortest prong.



203.13

Figure 11-12.–Types of cotter pins.



203.8

Figure 11-13.–Clamps.

Clamps

The clamps used on ground support equipment are used to prevent lines from chafing on other parts of the equipment. They are also used to fasten or support other components mounted on the equipment.

Two types of clamps and their uses in supporting flexible and rigid lines can be seen in figure 11-13. These clamps may differ in purpose in that one clamp is designed with a rubber or teflon cushion for low-range temperatures, and the other has an asbestos cushion for high temperatures.

Support clamps should be inspected for deterioration of the cushion material to prevent the metal part of the clamps from cutting or chafing the supported lines or hoses. The ASM should choose a clamp of the correct size and heat range and ensure that it is in good condition for installation. Figure 11-14 illustrates six ways to secure lines and hoses to each other with support clamps to maintain line clearances and prevent chafing.

FUELS

Petroleum products have always been important to modern military operations. These products are no less important to the ASM. This chapter covers petroleum products as related to aviation support equipment.

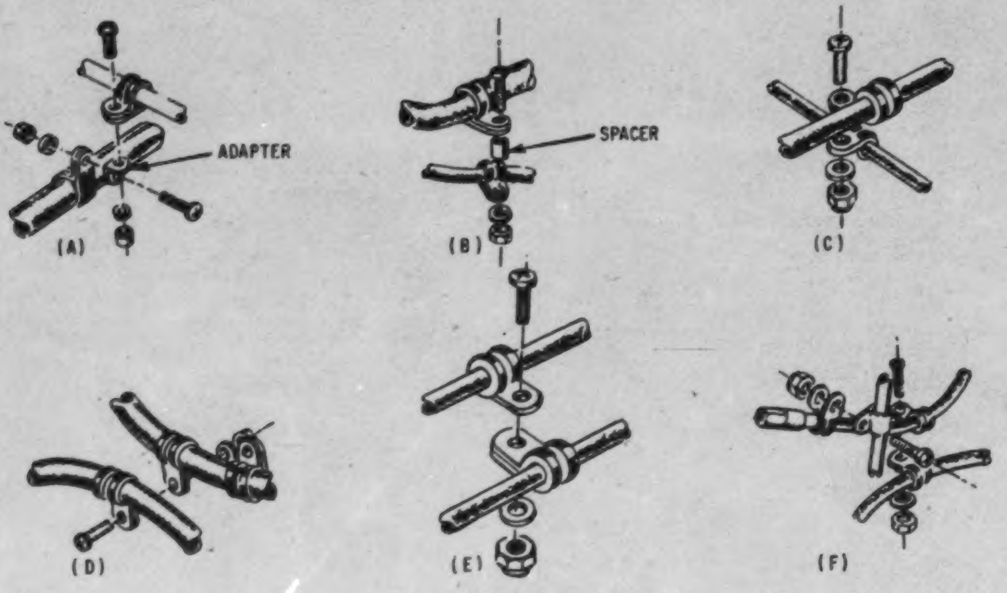
Crude oil is pumped from the earth in all areas of the world. The Middle East is the largest producer of crude oil in the free world. The Western Hemisphere is the second largest producer. North Africa has recently become a large producer of crude oil.

Refining of crude oil furnishes many usable products. Figure 11-15 illustrates the refining process and lists the results. The ASM is interested in automotive gasoline, diesel fuel, lubricating oil and grease, and hydraulic fluids.

Chapters 7 and 8 of this training manual covered the use of petroleum products in gasoline and diesel engines. Functional identification tape markings of rigid metal tubing appear in chapter 15 of this training manual. This chapter is concerned with the characteristics of petroleum products and their handling and treatment before their use in aviation support equipment.

GASOLINE

Gasoline contains two important elements (carbon and hydrogen) in such proportion that they burn freely in air and liberate heat energy.



213.4

Figure 11-14.—Securing lines using support clamps.

Gasoline is suited to engine operation because of its uniform rate of burning and easy vaporization to give quick starting in cold weather. The major properties of gasoline that affect engine operation are volatility, purity, and antiknock quality.

As applied to gasoline, volatility is the tendency to change from liquid to vapor at any given temperature. The volatility of gasoline affects ease of starting, length of the warmup period, and engine performance during normal operation. As the temperature rises and the pressure against the surface of the gasoline decreases, the rate of vaporization increases.

To start readily, an engine must have a burnable air-fuel mixture in the combustion chamber at the moment of starting. The proper mixture during normal operating conditions is about 15 parts of air to 1 part of fuel by weight, but during starting, when an engine is cold, some of the vaporized fuel condenses and collects in the intake manifold. More fuel must be added to make enough fuel available for starting and operation until the engine reaches operating temperatures. Under extremely cold starting conditions the air-fuel ratio may be as low as 1 1/4:1 in order to obtain the necessary 15 parts of air to 1 part of combustible fuel. The change in ratios for starting is accomplished by the choke in the carburetor. Starting in cold weather can also be aided by using fuels of higher volatility.

Vapor lock is a difficulty encountered in using highly volatile fuels. This tendency increases as the temperature gets hotter. A fuel that has a tendency to vaporize at normal atmospheric temperatures may form so much vapor in the fuel lines that the action of the pump does not provide a flow of fuel to the carburetor but a flow of vapor. Insulation between the fuel lines, fuel pump, and carburetor, and the heat producing parts of the engine (exhaust manifold and pipe) helps to prevent vapor lock. The use of low volatility fuels in hot weather is the best preventive.

In case it is necessary to bleed the fuel line to remove vapor lock or contamination, disconnect the line from the tank at the fuel

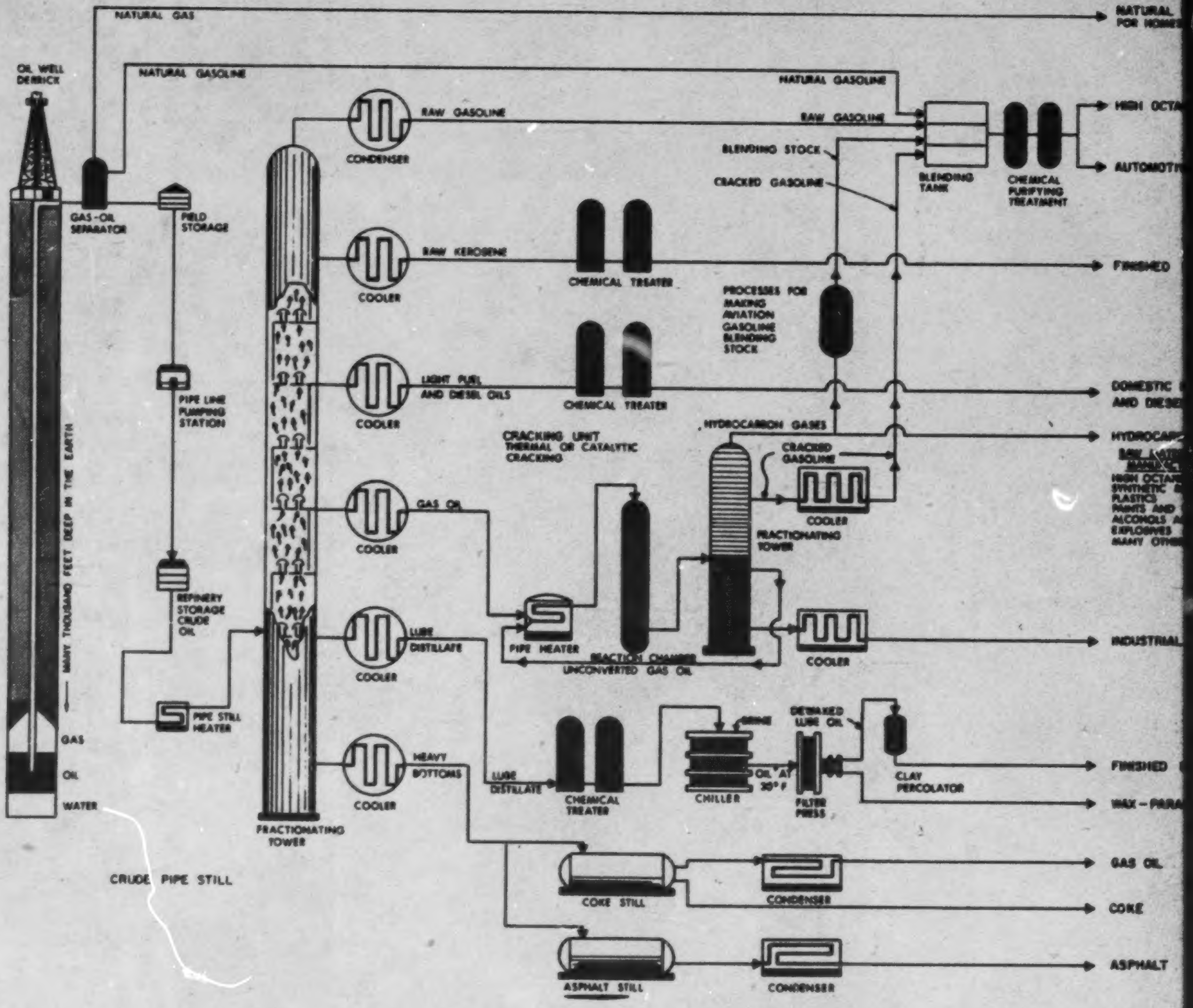

NATURAL GAS
NATURAL
FOR HOME
OIL WELL DERRICK
NATURAL GASOLINE
NATURAL GASOLINE
RAW GASOLINE
RAW GASOLINE
CONDENSER
BLENDING STOCK
CRACKED GASOLINE
BLENDING TANK
CHEMICAL PURIFYING TREATMENT
HIGH OCTA
AUTOMOTI
GAS-OIL SEPARATOR
FIELD STORAGE
RAW KEROSENE
COOLER
CHEMICAL TREATER
FINISHED
PROCESSES FOR MAKING AVIATION GASOLINE BLENDING STOCK
PIPE LINE PUMPING STATION
LIGHT FUEL AND DIESEL OILS
COOLER
CHEMICAL TREATER
DOMESTIC
AND DIESE
HYDROCARBON GASES
HYDROCAR
RAW MATE
MANUF
HIGH OCTAN
SYNTHETIC
PLASTICS
PAINTS AND
ALCOHOLS A
EXPLOSIVES
MANY OTHE
CRACKING UNIT THERMAL OR CATALYTIC CRACKING
CRACKED GASOLINE
COOLER
FRACTIONATING TOWER
MANY THOUSAND FEET DEEP IN THE EARTH
GAS OIL
COOLER
PIPE HEATER
REACTION CHAMBER
UNCONVERTED GAS OIL
COOLER
INDUSTRIAL
REFINERY STORAGE CRUDE OIL
LUBE DISTILLATE
COOLER
PIPE STILL HEATER
GAS
OIL
WATER
HEAVY BOTTOMS
COOLER
LUBE DISTILLATE
CHEMICAL TREATER
CHILLER
BRINE
OIL AT 30° F
DEWAXED LUBE OIL
FILTER PRESS
CLAY PERCOLATOR
FINISHED
WAX-PARA
FRACTIONATING TOWER
CRUDE PIPE STILL
COKE STILL
CONDENSER
GAS OIL
COKE
ASPHALT STILL
CONDENSER
ASPHALT

Figure 11-15.—Flow chart tracing crude oil from well to finished products.

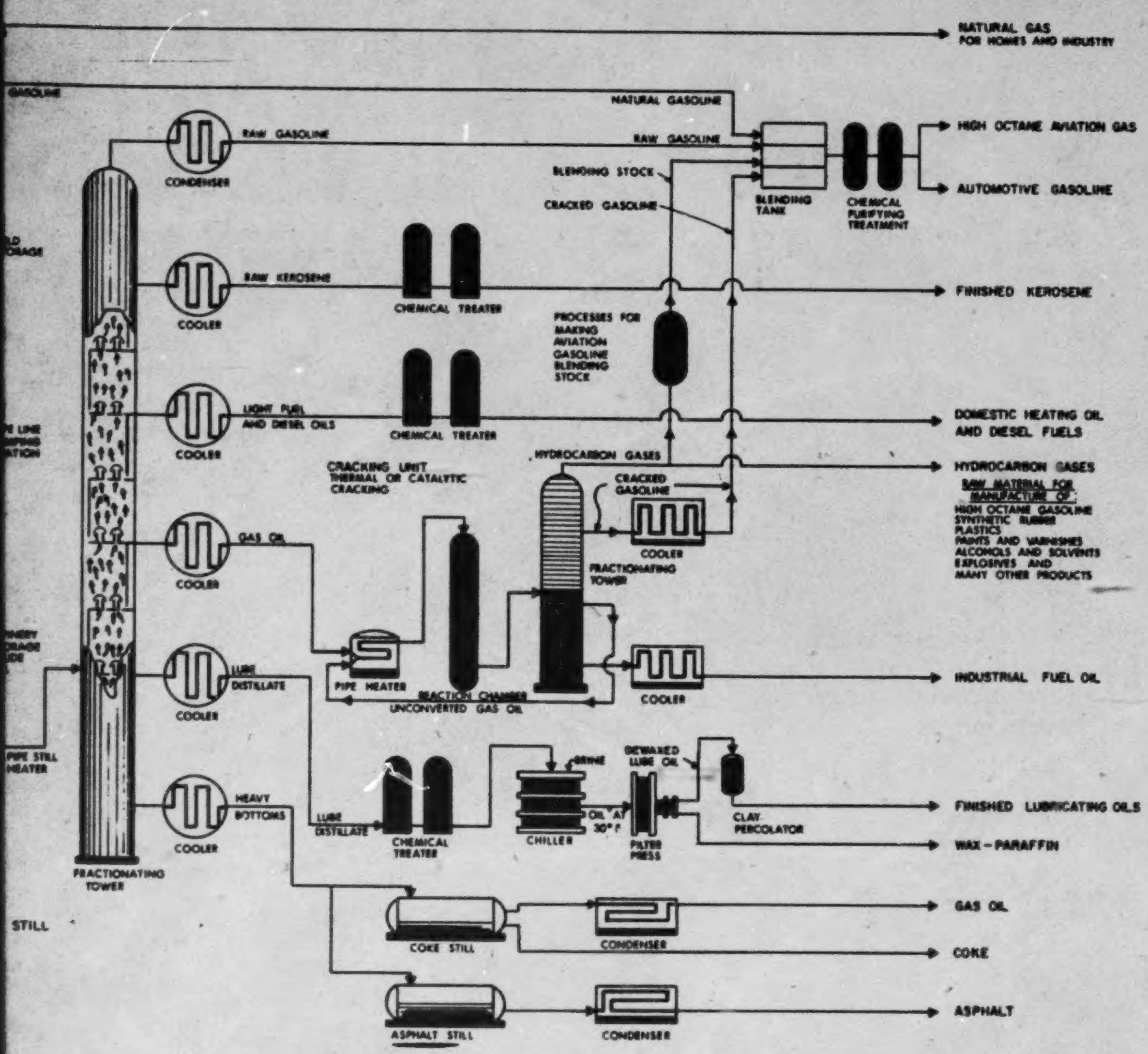

NATURAL GAS
FOR HOMES AND INDUSTRY
GASOLINE
NATURAL GASOLINE
RAW GASOLINE
CONDENSER
RAW GASOLINE
BLENDING STOCK
CRACKED GASOLINE
BLENDING TANK
CHEMICAL PURIFYING TREATMENT
HIGH OCTANE AVIATION GAS
AUTOMOTIVE GASOLINE
RAW KEROSENE
COOLER
CHEMICAL TREATER
FINISHED KEROSENE
PROCESSES FOR MAKING AVIATION GASOLINE BLENDING STOCK
LIGHT FUEL AND DIESEL OILS
COOLER
CHEMICAL TREATER
DOMESTIC HEATING OIL AND DIESEL FUELS
CRACKING UNIT THERMAL OR CATALYTIC CRACKING
HYDROCARBON GASES
CRACKED GASOLINE
HYDROCARBON GASES
RAW MATERIAL FOR MANUFACTURE OF:
HIGH OCTANE GASOLINE
SYNTHETIC RUBBER
PLASTICS
PAINTS AND VARNISHES
ALCOHOLS AND SOLVENTS
EXPLOSIVES AND
MANY OTHER PRODUCTS
GAS OIL
COOLER
COOLER
FRACTIONATING TOWER
PIPE HEATER
REACTION CHAMBER
UNCONVERTED GAS OIL
LUBE DISTILLATE
COOLER
COOLER
INDUSTRIAL FUEL OIL
PIPE STILL HEATER
HEAVY BOTTOMS
COOLER
LUBE DISTILLATE
CHEMICAL TREATER
BRINE
CHILLER
OIL AT 30° F
DEWAXED LUBE OIL
FILTER PRESS
CLAY PERCOLATOR
FINISHED LUBRICATING OILS
WAX - PARAFFIN
FRACTIONATING TOWER
STILL
COKE STILL
CONDENSER
GAS OIL
COKE
ASPHALT STILL
CONDENSER
ASPHALT

Figure 11-15.—Flow chart tracing crude oil from well to finished products.

227.67

pump. Apply pressure to the tank and permit the fuel to flow into a container until the vapor lock is removed or the contamination has passed into the container. Reconnect the line to the inlet side of the fuel pump. If the first attempt is not successful, repeat the process.

Another undesirable condition results when cold weather or overchoking leaves excessive amounts of fuel unvaporized in the intake and combustion systems. The unvaporized fuel seeps by the valves and piston rings into the crankcase and lubricating oil during starting and warmup. This dilutes the oil in the crankcase and reduces its lubricating qualities. If the engine operating temperatures are high enough, the gasoline will be vaporized in the crankcase and be withdrawn through the crankcase ventilating system.

When fuel is not distributed evenly to all cylinders, the engine will run unevenly, and power output will decrease. The fuel must be completely vaporized and mixed with air in the manifold before entering the cylinders to ensure good distribution. Quick, smooth acceleration also depends on a fully vaporized air-fuel mixture entering the combustion chamber.

The refining process removes many impurities from petroleum before gasoline suitable for engine use is produced. Considerable corrosion at one time was caused by sulfur inherent in crude oil, but modern refining procedure has made corrosion almost negligible. The tendency for the hydrocarbons in gasoline to combine with the oxygen in the air to form sticky gums which resulted in clogged carburetors, stuck valves, and other operational difficulties was another problem. Chemicals that control the gumming tendency are now added to the gasoline. Other impurities such as dirt, water, grease, and unwanted chemicals must also be removed to make gasoline an acceptable fuel.

Types and Designations

To better understand what is meant by the antiknock quality of gasoline, let us first study the process of combustion. When the mixture in the combustion chamber of an engine cylinder is ignited, the gasoline vapor and the oxygen in the air unite in a rapid chemical reaction called burning. In burning, the molecules of the gasoline and oxygen are set into very rapid motion, and heat is produced. The molecules bombard the walls of the combustion chamber and the piston head. This bombardment is what actually registers the heavy push on the piston and forces it down on the power stroke. The normal combustion process goes through three stages that can be termed formation of a nucleus of flame, hatching out, and propagation.

As soon as the spark jumps the gap of the sparkplug electrodes, a small ball of blue flame develops in the gap. This ball is the first stage or nucleus of flame. It enlarges with relative slowness, and there is no measurable pressure created by heat during its growth.

As the nucleus enlarges, it develops into the hatching-out stage. The nucleus is torn apart so that it sends fingers of flame into the mixture in the combustion chamber. This causes enough heat to give just a slight rise in the temperature and pressure in the entire air-fuel mixture. A lag still exists in the attempt to raise the pressure in the entire cylinder.

It is during the propagation stage that effective burning occurs. The flame now burns in a front which sweeps across the combustion chamber, burning rapidly and causing great heat and a rapid rise in pressure. This pressure causes the piston to move downward. The burning during normal combustion is progressive. It increases gradually during the first two stages, but the flame is extremely strong as it sweeps through the combustion chamber during the third stage. However, there is no violent or explosive action such as when detonation takes place.

If detonation does take place, it occurs during the third stage of combustion. The first two stages are normal, but in the propagation stage the flame sweeps from the area around the spark plug toward the walls of the combustion chamber. As the flame races through the combustion chamber, the unburned gases ahead of it are further compressed and are heated to high temperatures. When the unburned mixture is compressed and heated to the point of self ignition, a rapid uncontrolled burning takes place that is almost an explosion and is called detonation. Knocking or pinging results. Detonation may cause malfunctions that range from loss in the performance to actual destruction of the engine. Pistons have been shattered, cylinders burst, and heads cracked in extreme cases. It is more likely that the engine will overheat, fuel consumption will be high, and a loss of power will result from detonation.

The ASM can help prevent detonation by making sure the gasoline used in the engine is the manufacturer's recommended octane rating. The ability of a fuel to resist detonation is a measure of its octane rating. Normal heptane has an octane rating of zero, and iso-octane has an octane number of 100. When these two hydrocarbons are mixed in the proper proportions to cause the same degree of knocking in the test engine as the gasoline being tested, the proportion gives the octane number of the gasoline. For example, a gasoline rating 75 octane is equivalent in its knocking characteristics to a mixture of 75-percent iso-octane and 25-percent normal heptane.

The tendency of a fuel to detonate varies in different engines and in the same engine under different operating conditions. Engines are designed to operate within a certain octane range. Performance is improved with the use of higher octane fuel within the range if the spark setting is changed accordingly. The spark should be advanced when higher octane fuel is used; it should be retarded when lower octane fuel is used. If the engine operates satisfactorily at the upper limit of the range of the octane rating for its fuel, it will not improve the performance to use fuel of a higher octane number. Octane rating of fuel has nothing to do with starting qualities, potential energy, volatility, or other major characteristics.

Tetraethyllead is the most commonly used compound added to gasoline to suppress detonation. It is effective because it reduces the rate of burning of the fuel and thus prevents explosive burning or detonation. Most gasolines used in aviation support equipment contain amounts varying up to one part tetraethyllead to 1,600 parts gasoline. Improved refining methods also have produced fuels of greater antiknock quality.

Low octane fuel is not the only cause of detonation. It can be caused by anything that increases the heat or pressure applied to the last part of the air-fuel mixture in the combustion chamber. That is why the compression ratio of an engine has an upper limit. Due to the excessive heat and pressure caused by additional compression when the ratio is raised too high, detonation will result. We can assume that the gasoline delivered to the Navy is of the specified octane rating; therefore, if an engine is detonating, we must look for other causes. Under certain conditions, preignition, excessive spark advance, lean fuel mixture, and defective cooling systems are some of the causes of detonation. Preignition is the igniting of the air-fuel mixture in the combustion chamber during the compression stroke before the spark has occurred. This is caused by a hot spot in the combustion chamber. For example, an overheated exhaust valve head, a hot spark plug, or a buildup of carbon could be the cause of preignition. When the engine becomes overheated, a part of the combustion chamber may become red hot and, as the air-fuel mixture is compressed, ignite the mixture. Preignition may lead to detonation, but the two are separate and distinct events.

DIESEL

Diesel fuels are heavier than gasoline because they are obtained after gasoline and kerosene have been refined from the crude oil. The high speed diesel engines used in aviation support equipment require a fuel almost as light as kerosene. This diesel fuel has specification requirements as exacting as does gasoline. The most important qualities of diesel fuel are cleanliness, viscosity, and ignition quality.

Cleanliness is probably the most important and necessary property of a diesel fuel. The fuel should not contain any foreign substances because fuel pump and injector malfunction will result. Diesel fuel will hold dirt in suspension for longer periods of time than gasoline because it has a higher viscosity. Because of this, every precaution must be taken to keep dirt out of the fuel system or eliminate it before it reaches the pumps. Water is more objectionable in diesel fuel than in gasoline because it causes ragged performance and will corrode the fuel system. The least amount of corrosion on the highly machined surfaces of the injection system equipment will cause it to become inoperative.

When it is suspected that contamination has caused unsatisfactory performance of a diesel engine, disconnect all supply lines and blow them out with air. Reconnect the lines, and ensure that uncontaminated fuel is supplied to the system.

The viscosity of a fluid is an indication of its resistance to flow. The higher the viscosity, the greater the resistance to flow. The viscosity of diesel fuel must be low enough to flow freely at the lowest temperatures encountered but at the same time be high enough to properly lubricate the closely fitted pump and injector plungers. It must be viscous enough that leakage at the pump plungers and dribbling at the injectors will not occur. The viscosity of the fuel determines the size of the fuelspray droplets. This size governs the atomization and penetration qualities of the spray.

The ignition quality of a diesel fuel is its ability to ignite spontaneously under the conditions existing in the engine cylinder. The ignition quality is the delay between the time the fuel is injected into the cylinder and ignition by the hot air, and is expressed as a cetane number. The spontaneous ignition point of the fuel is a function of temperature, pressure, and time. The apparatus used for measuring the cetane number of a fuel is an actual diesel cylinder running under controlled operating conditions. The cetane number of a fuel is obtained by comparing the operation of the unknown fuel with a known reference fuel in a special test engine. The reference fuel is a mixture of alpha-methyl-naphthalene (which will hardly ignite alone) and cetane (which will readily ignite at temperatures and pressures obtained in a diesel cylinder). The cetane number indicates the percent of cetane in a reference fuel which just matches the ignition properties of the fuel being tested.

Diesel engines knock, particularly when first started or when idling. This knock is due to the rapid burning of the charge of fuel accumulated during the delay period between the time of injection and ignition. When fuel is injected, the first portion must vaporize, then heat and pressurize until it reaches the spontaneous ignition point. Time is required for sufficient fuel to go through this cycle to permit ignition. During this same time, other portions of the fuel are being injected and are going through the same phases but behind the first portion. Therefore, as the flame spreads from the point of ignition many of the portions of the charge reach their spontaneous ignition temperatures at practically the same time. This rapid burning causes a very rapid increase in pressure which causes a distinct and audible knock. Increasing the compression ratio in the cylinder of the diesel engine will decrease the ignition lag and thereby decrease the tendency to knock. Speeding up the engine increases the compression ratio. The type of combustion chamber, airflow within the chamber, the type of nozzle, the injection pressure conditions, the fuel temperature, the air temperature, and the characteristics of the fuel are all factors that could affect knocking in a diesel engine. As was seen in chapter 8 of this manual, more can be done in the design of the diesel engine cylinder to eliminate detonation than can be done in a gasoline engine.

The cetane number of diesel fuels is usually between 30 and 60. Rapidly igniting fuels have high cetane numbers while slow igniting fuels have low cetane ratings.

JP-5

JP-5 fuel predominantly consists of hydrocarbons with a little more carbon and somewhat less hydrogen. It may contain as much as 4 pounds of sulfur per 1,000 lb of fuel.

Compounds containing only hydrogen and carbon release, when burned, the greatest amount of energy for a given weight of fuel. Thus, a fuel consisting only of hydrogen and carbon may produce 2-1/2 horsepower per hour for each pound of fuel burned by a piston engine.

Since JP-5 is a less volatile fuel than JP-4, it is now the Navy's primary jet fuel. It is safer to store, more thermally stable, and has higher heat content per gallon than JP-4.

JP-5 is a kerosene-type fuel with a vapor pressure close to O psi. Since it has a lower tendency to vaporize than the more volatile grades, the vapor-air mixture in tanks or containers above its liquid surfaces will generally be too lean to be ignited until the surface of the liquid reaches a temperature of about 140° F. JP-5 is used by all shipboard diesel-powered support equipment and gas turbine engines.

Safe Handling of JP-5

JP-5 fuel does not contain tetraethyllead. However, it may contain more toxic aromatics than gasoline. It should, therefore, be handled with the same health precautions as apply to gasoline. The hygienic or health aspects for gasoline, therefore, apply equally as well to JP-5. This includes precautions covering inhalation of vapors, skin irritations, and container hazards.

Jet engine fuels are petroleum products manufactured from crude oil by oil refineries. They are classified as flammable liquids. This means that they will burn when ignited. Under proper conditions they will explode with forces similar to those of TNT or dynamite. Death can result if the vapors of fuel are inhaled in sufficient quantities, and serious skin irritations can result from contact with the fuel in the liquid state. In liquid form fuels are lighter than water, and in the vapor form they are heavier than air. Consequently, any water present in the fuels will usually settle to the bottom of the container. On the other hand, vapors of these fuels, when released in the air, tend to remain close to the ground, thus increasing the danger to personnel and property. From safety and health standpoints jet engine fuels must be handled with caution. On rags or waste they are very flammable.

The Standard First Aid Training Course, NAVEDTRA 10081-B, should be studied by all personnel working with fuels for information on the treatment of those overcome or injured due to the handling of fuels.

LUBRICANTS

The primary purpose of any lubricant is to reduce friction and eliminate metal-to-metal contact during the operation of the engine. Lubricants provide a film which permits surfaces to slide over each other with less friction. Therefore, lubrication is essential to prevent wear in any mechanical device where there are surfaces rubbing against each other.

OILS

In internal combustion engines, lubricating oils must perform four basic functions: lubrication, cooling, cleaning, and sealing. In order to properly lubricate the engine parts the oil must be of low enough viscosity to flow readily between closely fitted parts that move rapidly but of high enough viscosity to prevent metal-to-metal contact between the parts. It must have a low enough pour point (lowest temperature at which it can be poured) to lubricate during starting under very low temperatures. The flashpoint of oil is the temperature at which it first gives off sufficient flammable vapor to ignite; this temperature ranges from 275° to 700° F. The fire point is the temperature at which the vapor will continue to burn and is usually 50° to 70° higher than the flashpoint. Lubrication oil must have high enough flash and fire points so that it will not burn, vaporize, or be consumed under high heat and be tough enough so that it will not break down or fail under high temperatures or pressures. The oxygen absorption of the oil must be low enough so that varnish and gum do not form, and the oil must have small enough acid content so as not to be detrimental to engine parts.

Lubricating oil must cool moving parts by carrying off waste heat. This is especially true in diesel engines. Diesel engines generate enough heat of combustion that an oil cooler is used to transfer the heat from the oil to another medium. In order to perform its cooling function, lubricating oil must be able to flow readily.

Another major function of lubricating oils is cleaning. This means carrying from the engine parts dirt, dust, small carbon and metal particles, gum, and varnish. Because of the increased compression ratios, higher speed engines, high operating temperatures, and closer tolerances, cleaning has become increasingly important in recent years. Filters have been developed to remove part of the dirt and ventilation systems have been designed to carry off vapors and moisture. However, these devices perform only part of the job. Therefore, additives or detergents are blended with lubricating oils. The detergent is soluble in the oil and cleans the dirt, gum, and other impurities from the engine and holds them in suspension. These suspended impurities are removed by the filter as the oil is circulated. Gum and varnish are not removed by the filter and therefore, the oil must be changed at intervals. If the oil is not changed, the amount of gum and varnish increases to the point where the oil can no longer hold them in suspension and these substances are deposited throughout the engine and cause poor performance.

Another function of lubricating oil is to seal the space between the piston rings, cylinder walls, and pistons to prevent leakage of combustion gases from the combustion chamber, past the rings, into the crankcase. When this space is properly sealed by the lubricating oil, the full force of the combustion is expended on the head of the piston and none of the force is lost.

Types and Designations

The military specification for lubricating oils for aviation ground support equipment prescribes that the oil be a petroleum or synthetically prepared product or a combination thereof. This oil is intended for the lubrication of internal combustion automotive equipment and for general purpose lubrication. This oil is of three viscosity grades: SAE10, SAE30, and SAE50. The SAE stands for the Society of Automotive Engineers who have established an arbitrary system for classifying motor oils according to their viscosities.

Other parts of the aviation support equipment use lubricating oils, in addition to the engine. These are the transmission, differential, and steering gear unit. A standard transmission uses SAE80 or SAE90 grade oil. This oil can also be used in the differential and steering gear unit. The manufacturer's recommended grade of oil should always be used in all three parts. The desirable qualities of a gear lubricant are high viscosity index, proper viscosity, chemical and thermal stability, and freedom from foaming. The viscosity index of an oil is the effect of change of temperature on the viscosity of the oil. A low viscosity index signifies a large change of viscosity with changes in temperature. For example, an oil that becomes very thin at high temperatures and very thick at low temperatures will have a low viscosity index. If uncompounded mineral oils were used in modern gear systems, they would fail in a short time because of the great friction generated and the high loads carried. Therefore, oiliness additives and extreme pressure agents are added to the mineral oil. Extreme pressure agents produce a nonscuffing film on the gears which increases the amount of load the gears can carry.

The oil used in an automatic transmission more closely resembles hydraulic fluid than lubricating oil. However, only automatic transmission oil should be used in automatic transmissions. This oil has been specially prepared for use in modern day automatic transmissions.

Turbine Oil

MIL-L-23699B is a synthetic base lubricating oil used in the lubricating system of support equipment gas turbine engines. This oil has two principal advantages over petroleum oil. It has less tendency to lay down lacquer and coke deposits and less tendency to evaporate at high temperatures. Its principal disadvantage is that it tends to blister or remove paint wherever it is spilled. Painted surfaces should be wiped clean with a petroleum solvent after spillage.

GREASES

Grease is used where oil cannot perform the desired lubrication. On aviation support equipment, grease is used in front wheel bearings and for chassis lubrication. The most important requirements of greases are stability, noncorrosiveness, water resistance, and satisfactory performance in operation. A grease must be stable both in storage and in use. It must be free from bleeding (separation of oil), oxidation, and changes in consistency. The grease must not chemically attack the metals and other materials with which it comes in contact. A grease which is insoluble in water is required in some cases, while in others the grease must only resist weathering or the washing action of water.

Various soaps are used in the manufacture of grease. These soaps regulate the water resistance and the heat stability of the grease. A grease must perform satisfactorily in the equipment for which it is intended, or inadequate lubrication will result. Always use the grade of grease recommended by the equipment manufacturer.

HYDRAULIC FLUIDS

Hydraulic fluid is used in brake systems, power steering, work stands, ordnance trucks (bomb lifting systems, both self-propelled and towed), aircraft spotting dollies, and forklifts. The necessary properties of a hydraulic fluid are to have chemical stability, freedom from acidity, lubricating ability, proper viscosity, a minimum of toxicity, and a high flashpoint. It should not undergo chemical changes that will form unfavorable deposits that clog openings or cause sticking or leaking of moving parts during severe operating conditions. Hydraulic fluids should be free from acids that would corrode or otherwise adversely affect the metals and nonmetal lines composing the system. Since moving parts are involved in the hydraulic system, the hydraulic fluid should have the ability to lubricate these moving parts. The viscosity of the hydraulic fluid must permit it to give a good seal at pumps, valves, and pistons and still permit it to flow easily under all operating conditions. Hydraulic fluid should be free from any chemical that is poisonous or toxic to the human being. Resistance to combustion and minimum evaporation are desirable qualities of hydraulic fluids and are indicated by a high flashpoint.

Several different types of hydraulic fluids are used in support equipment. The manufacturer of the equipment recommends the specification to be used in each system. The most commonly used hydraulic fluid is Specification MIL-H-5606B. This is the same type of fluid that is used in aircraft hydraulic systems. The fluid is colored red and is normally procured in 1-quart and 1-gallon containers, also colored red. MIL-H-5606B hydraulic fluid has a petroleum base and must not be mixed with vegetable base hydraulic fluid.

Vegetable base hydraulic fluid is used in the brake systems of some self-propelled support equipment. When petroleum or mineral base hydraulic fluid is mixed with vegetable base hydraulic fluid in a system, the two will jell and make the system inoperative. Using a petroleum base hydraulic fluid in a vegetable base hydraulic system will cause the natural rubber seals to decompose and clog the system and also cause the seals to leak. Vegetable base hydraulic fluid has no deteriorating effect on the petroleum base hydraulic synthetic rubber seals. Be sure the hydraulic fluid you add, or with which you refill a system, is the type for which the system is designed.

Cleanliness is the most important factor in the maintenance of a hydraulic system. Small orifices and close clearances in the hydraulic system make all forms of dirt a positive hazard. The usual cause of foreign matter in the system is carelessness of those who service the system. When adding fluid to the system make certain that the manufacturer's recommendation is followed as to the type. Also ensure that no dirt gets in the reservoir when the cap is removed. Since the ASH normally repairs and maintains the hydraulic systems of the aviation support equipment, adding fluid is usually the most the ASM will be required to do.

HANDLING PETROLEUM PRODUCTS

SAFETY

Hazards in handling petroleum products are usually confined to handling gasoline. Vapors from all petroleum products are hazardous because they constitute fire and explosive hazards, and they are toxic to the human body. When petroleum products, even gasoline, are stored in a closed can or tank they are not hazardous because no vapor (or very little) escapes from the container. To use the petroleum product it must be handled, and this permits vapors to form. Since the vapors from petroleum products create the greatest hazard, the vapor characteristics should be understood. Vapors from petroleum products, especially gasoline, have been known to travel some distance, reach a source of ignition, and flash back to the point of origin causing a fire. Vapors from petroleum products are heavier than air and settle in low places, such as lubrication pits, where they remain until ventilated out. Spilled gasoline or diesel fuel vaporizes quickly because so much of the liquid is exposed to the air; therefore, when spilled it should be cleaned up as soon as possible.

Gasoline is volatile because it gives off flammable vapors at comparatively low temperatures. Volatile products such as gasoline are normally handled at temperatures where they give off sufficient vapors to burn at all times. Therefore, the ASM must be extremely cautious when fueling aviation support equipment with gasoline. Caution is also required when handling other petroleum products but not to the same degree as in handling gasoline.

A hazard to persons handling petroleum products is the toxic effect of the vapor. Petroleum vapors, when breathed in a concentration of one-tenth of one percent by volume, may cause dizziness at the end of 6 minutes. Concentration of one-half of one percent can cause the inability to walk straight in 4 minutes. Longer exposure or greater concentration may cause unconsciousness or death.

The first symptoms of breathing toxic vapors are headaches, nausea, and dizziness. Recovery from the early symptoms is usually prompt after removal to fresh air. If a man becomes unconscious because of breathing petroleum vapors, he should receive immediate medical attention.

The hazard of heavy concentrations of vapors from gasoline is increased if the gasoline contains tetraethyllead which is added for antiknock purposes. This lead compound is inhaled with the fumes or may enter the body through the mouth or by absorption through the skin. No matter how it enters the body, tetraethyllead is poisonous. Although the amount of tetraethyllead blended with automotive gasoline is very small, lead poisoning may occur from repeated exposure to gasoline vapors in an enclosed or inadequately ventilated area where leaded gasoline has been spilled in considerable quantity. If operating personnel are continually exposed to leaded gasoline, they should be rotated on the job in order to limit the period of individual exposure. A better solution is to provide sufficient ventilation to remove the hazard.

Volatile products such as gasoline may cause skin irritations if allowed to remain in contact with the skin, particularly under soaked clothing and gloves. Clothing or shoes should be removed at once if any fuel has soaked through them. After clothing removal, the skin should be washed with soap and water. If the skin is subjected to repeated contact with gasoline, the protective oils are removed from the skin and drying, roughing, cracking, and possibly infections of the skin result. Oil-resistant rubber gloves should be worn as protection by those handling petroleum products.

If volatile fuel gets into the eyes, first aid should be given immediately. Thoroughly wash the eyes with water, apply sterile olive oil, castor oil, or mineral oil to the eye and secure medical attention as soon as possible. If a petroleum product is swallowed, immediately give the victim a large quantity of warm, salty water to drink in order to induce vomiting. Medical attention should be secured as soon as possible.

STORAGE

Petroleum products are stored in cans, drums, and tanks. Gasoline and diesel fuel are usually stored in drums or tanks. Lubricating oils are usually stored in cans or drums. Grease and hydraulic fluid are usually stored in cans.

Because gasoline is very flammable it should be stored outside. The safest method of storage is in an underground ventilated tank. The aviation support equipment is then serviced by a pump similar to those used in civilian service stations everywhere. The storage tank may be mounted on a truck. The truck engine will then supply the power to run the pump to move the fuel to the equipment serviced. If stored in drums, the gasoline is removed by a hand operated pump or by gravity draining, depending on facilities available. Regardless of the method of storage, spillage while servicing equipment becomes a problem. Vapors of gasoline may be ignited by the vehicle serviced when it is started. If much spillage results from servicing the vehicle it should be flushed away with water before the vehicle is started. The fueling area should be posted with signs prohibiting smoking or any open flame. Adequate firefighting equipment should be available in the fueling area. Dry chemical and CO_2 fire extinguishers are the best for petroleum product fires. To eliminate static electric sparks that can ignite gasoline vapors while being fueled, the equipment should be grounded. If fueling from a tank truck, the truck should also be grounded. A wire or chain securely fastened to the tank truck or vehicle and extending to the deck is considered sufficient grounding. Aboard ship, gasoline is usually stored in drums. The gasoline is transported in cans to the equipment being fueled.

Safety cans are designed for the safe handling of gasoline in quantities up to 10 gallons. These cans are made for use inside where no provision has been made for a special storage room of proper construction. They can also be used to transport gasoline outside. Each can is cylindrical in form and has a self-closing valve which is opened through a valve actuating linkage by manual pressure applied to either the carrying handle or an independent control lever. Internal pressure in excess of 5 pounds per square inch is relieved either through an independent pressure relief valve or by overcoming the spring pressure on the pouring closure or the filling closure. Both the filling and pouring openings are provided with double screeens of such design that they serve as flashback arresters in the event that the flammable vapor should ignite outside the can. These screens can be readily removed and replaced without forcing, thus facilitating frequent inspection and cleaning. The valves are leakproof, so the can, when filled with liquid, can be inverted without danger of leakage. The stability of the can is such that it will not tip over of its own accord when it contains liquid and is tilted 30 degrees from the horizontal.

Preventive measures are always more safe than corrective measures. Therefore, if no spillage occurs and no unsafe handling practices are permitted, danger is held to the minimum.

Diesel fuel ashore is usually stored in skid-mounted tanks outside. Aviation support equipment can be fueled from the tank by gravity feed. Though diesel fuel is not as flammable as gasoline, the same precautions should be followed as have been listed for handling gasoline. Diesel fuel aboard ship is stored in drums, and the fueling of equipment is performed in the same way as with gasoline.

Lubricating oils are stored in drums or cans. When stored in drums, the drum is usually fitted with a faucet to permit the oil to be drained into containers for transportation to the equipment where it is needed. When oil comes in cans, a pouring spout can be inserted for pouring into the equipment. Lubricating oils can be stored inside.

Grease and hydraulic fluid are usually supplied in cans. The cover or cap of the can should always be replaced to prevent any foreign matter getting in the unused portion. Grease and hydraulic fluid can be stored inside.

CONTAMINATION

It has already been stated that contamination in petroleum products should be avoided. Where unused petroleum products are stored in drums or cans they should be tightly closed to prevent dirt from entering the container. Every precaution should be taken to prohibit foreign matter from getting in gasoline, diesel fuel, lubricating oil, or hydraulic fluid.

Where it is suspected that the fluid is contaminated it should be filtered before using.

Empty drums and reusable cans not immediately scheduled for refilling with the same fluid should be cleaned before storage. Empty containers should be protected from careless handling and from contamination of the interior. They should be tightly closed, as this will also retard interior corrosion to a great degree. If the container shows evidence of corrosion, it should be scheduled for possible reclamation. Empty containers having contained flammable or explosive products should be treated as a hazard and handled as such until reconditioned or cleaned.

CHAPTER 12

GAS TURBINE COMPRESSORS

The ASM is required to maintain and repair gas turbine engines used in ground support equipment. The prolonged life and operational readiness of the gas turbine engines invariably depend upon the familiarity maintenance personnel have with the equipment.

It is essential that the ASM know the engine as thoroughly as possible. He should know what it is designed to do and how it fulfills that function. The ASM should be familiar with normal operating details of the engine, such as oil pressures, temperatures, and consumption; fuel pressures, flows, and consumption; and exhaust gas temperatures. All of these should be known for the operating conditions from starting to idle, from idle to load, and from load to shut down of the engine.

DESCRIPTION AND PURPOSE OF GAS TURBINE ENGINES

Basically, there are two types of gas turbine engines, the centrifugal-flow type and the axial-flow type. (See figures 12-1 and 12-2.) By observing the illustrations of the two types, it can be seen that the greatest single difference is in the compressor section. The construction features of the COMPRESSOR (axial-flow or centrifugal-flow) determine the designation of the engine.

The centrifugal-flow compressor type engine is the most common engine used in support equipment. The advantages of the centrifugal-type as compared to the axial-flow type are as follows:

1. Simplicity of design and manufacture, thus lower cost.

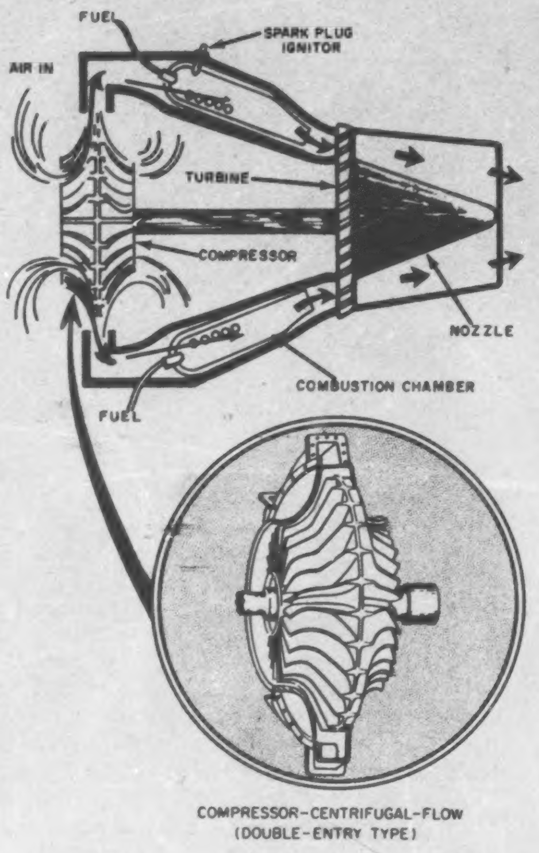


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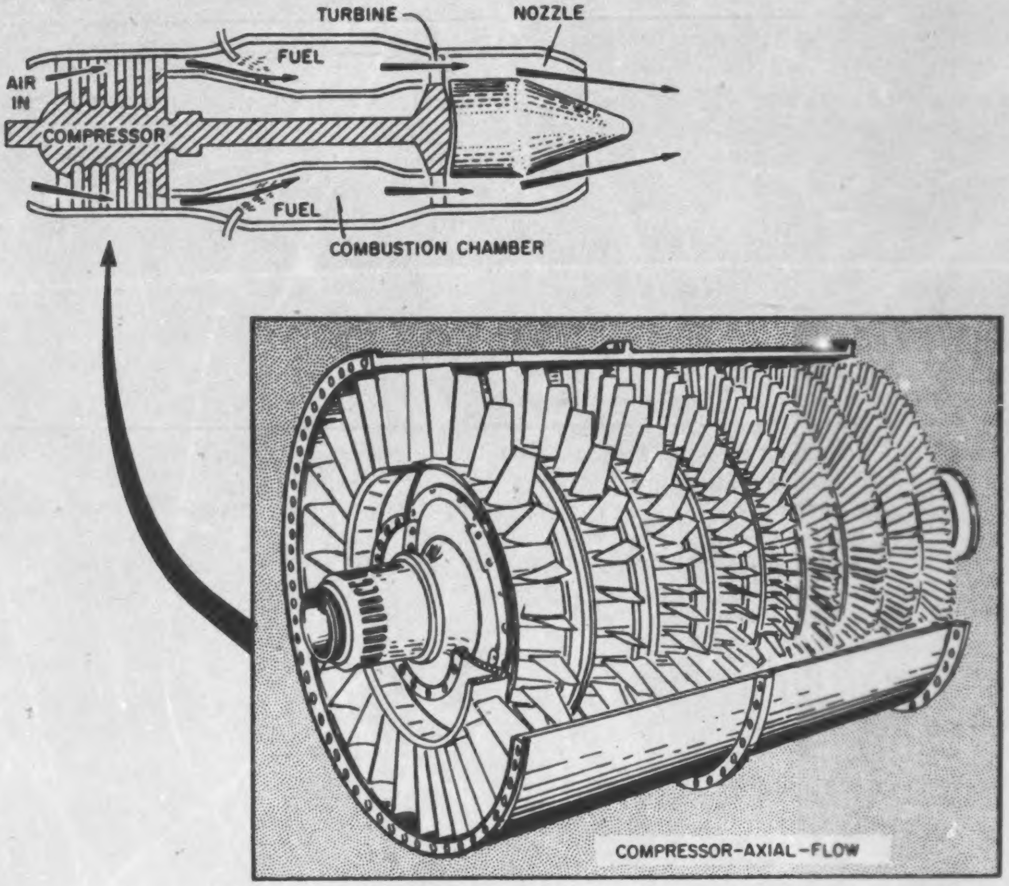
Figure 12-1.—Centrifugal-flow type engine.


TURBINE
NOZZLE
FUEL
AIR IN
COMPRESSOR
FUEL
COMBUSTION CHAMBER
COMPRESSOR-AXIAL-FLOW

224.99

Figure 12-2.—Axial-flow type engine.

2. Lighter weight.
3. Low starting power requirements.

Because the centrifugal-flow engine is the most commonly used in support equipment, the axial-flow is not discussed in this chapter. By understanding the centrifugal-flow type, the axial-flow type can also be understood, since all other sections and components except the compressor are very similar in design and operation, if not identical.

The gas turbine engine consists of the following major sections and systems:

1. Accessory section.
2. Compressor section.
3. Turbine section.
4. Fuel system.
5. Lubrication system.
6. Electrical system.

A discussion of each section and each system is presented later in this chapter.

TYPES OF GAS TURBINE COMPRESSOR UNITS

Gas turbine compressors provide pneumatic power in the form of compressed bleed air for operation of large-class pneumatic equipment. This equipment includes aircraft main engine starters and other types of compressed air consumers. These units can also be used safely for the removal of ice and snow from aircraft surfaces and for heating and preheating. Usually the units are self-contained and require only an outside source of fuel and oil to maintain a constant output.

There are many types of configurations of gas turbine compressors; however, because of their similarity in construction and operation, the gas turbine compressor and its systems and configurations are discussed generally in this chapter.

CONFIGURATION OF GAS TURBINE COMPRESSORS

The major differences in the enclosures may be determined by where the gas turbine is generally used. Some are enclosed in pods as shown in figure 12-3. This allows for the pod to

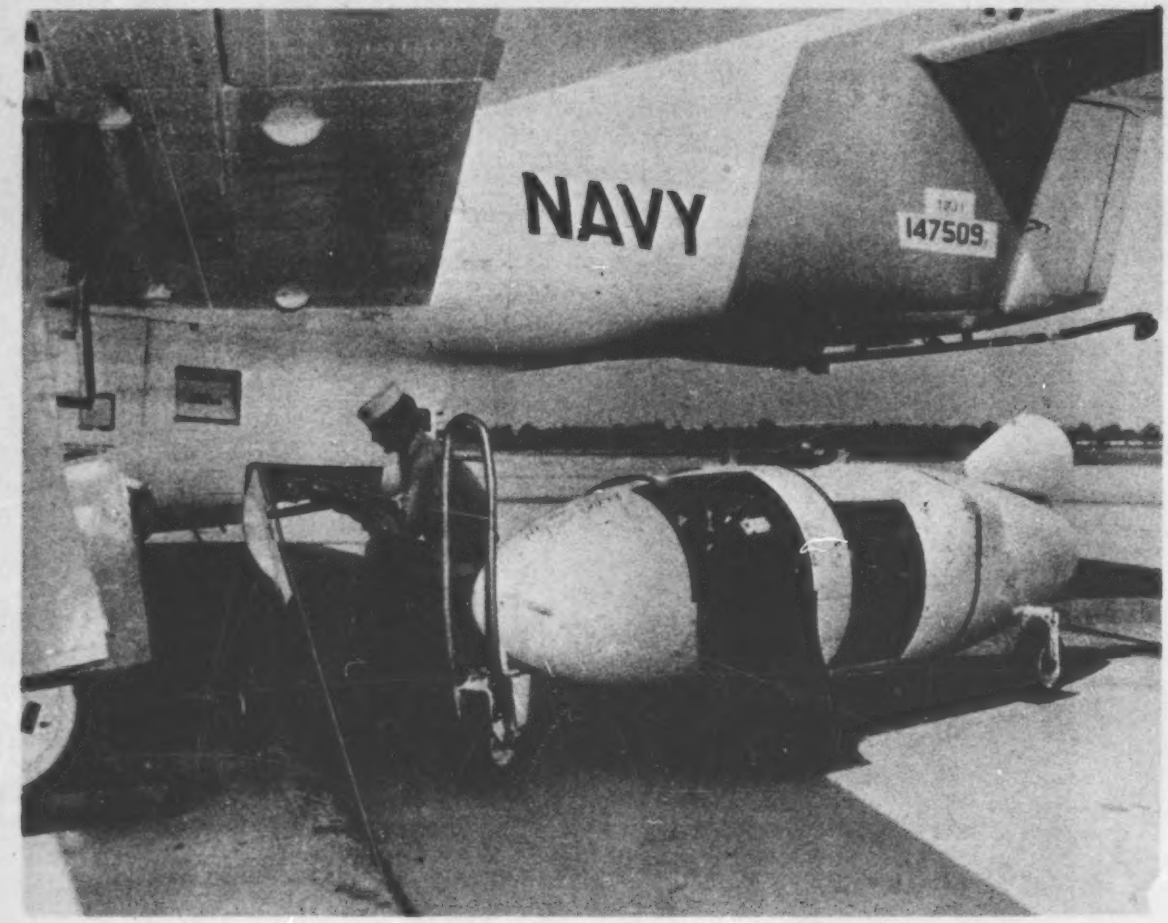


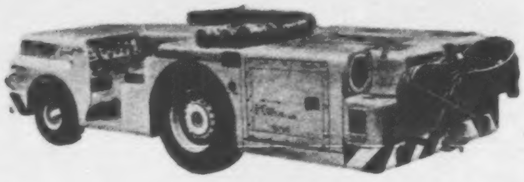
Figure 12-3.—GTC 85 compressor in a pod. 227.68

be suspended from the wing of an aircraft for flyaway. These pods are normally used on air stations and in rare occasions may be aboard aircraft carriers. Another type will be found aboard aircraft carriers as shown in figure 12-4. This unit is mounted on the MD-3 tractor so that less space will be taken up on the carrier. It can be used to start all aircraft except the reciprocating engine aircraft.

The model NCPP-105 compressor power unit, shown in figure 12-5 is a complete, self-contained unit consisting of a flyaway assembly enclosed in a skid-mounted, weather-resistant enclosure. Some models of the NCPP-105 are mounted on trailers for ease of movement from aircraft to aircraft or place to place. The NCPP-105 supplies compressed air, at two pressure ratios (5:1 and 3.6:1), for aircraft engine starting, and ac and dc electrical power for operation of aircraft ac and dc electrical components. The NCPP-105 is equipped with a remote cable assembly, an ac output cable, a dc output cable, and a bleed air duct assembly.

The unit enclosure consists of a forward and aft enclosure (hinged together), a cable stowage enclosure, muffler assembly, fuel tank, structure assembly, and a base assembly.

The flyaway assembly, shown in figure 12-6 is normally operated while in the NCPP-105 unit enclosure, with the dc power supply mounted in the forward enclosure. However, when it is required to transport the flyaway assembly by aircraft to a temporary location, the dc power supply is removed and relocated on the flyaway assembly structure. The fuel line and ac and dc electrical output cables are disconnected, the forward and aft enclosures are lifted off the structure assembly, and the flyaway assembly is then removed from the base assembly. The flyaway assembly, with its remote cable, ac and dc electrical output cables, and bleed air duct assembly, upon arrival at its temporary location, can be operated by attaching it to a fuel supply.



199.10

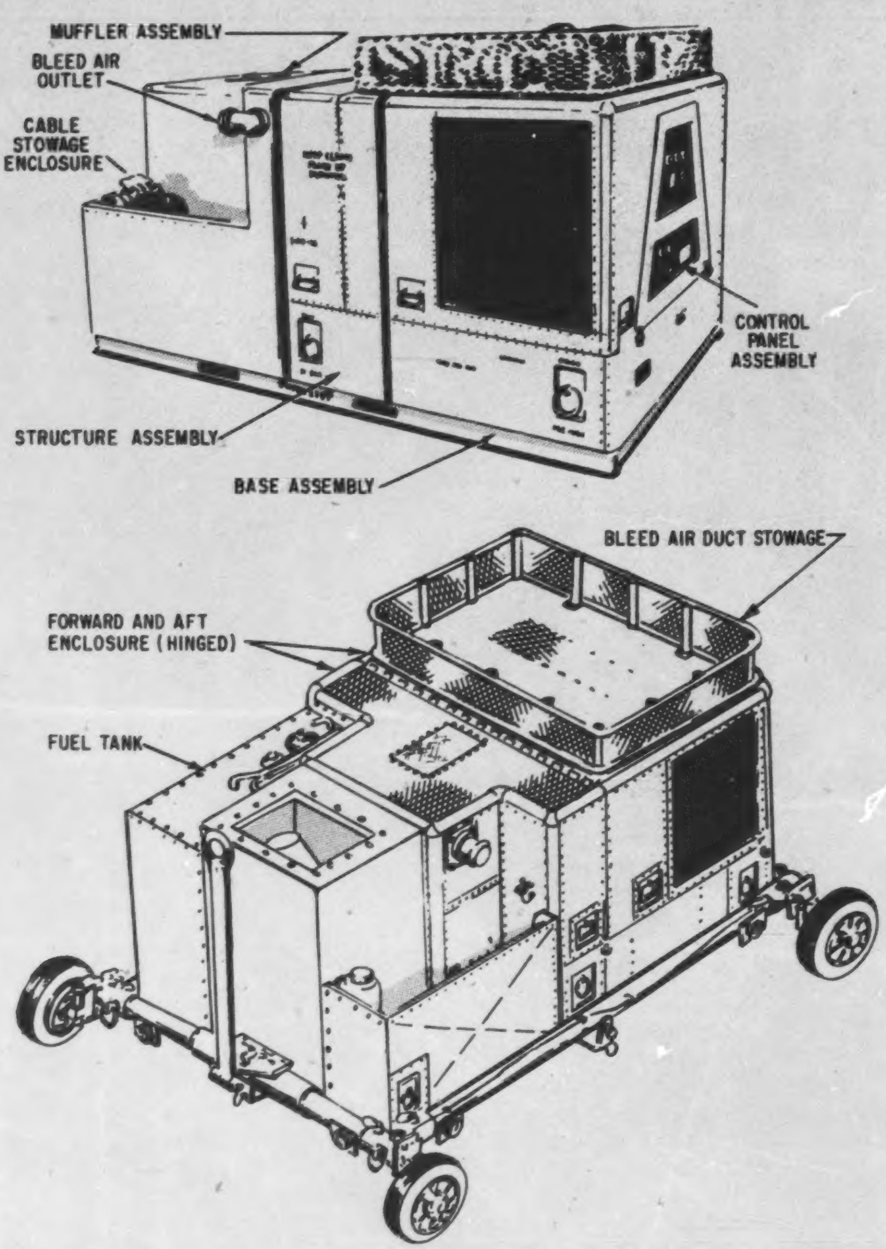
Figure 12-4.—MD-3A tow tractor.

OPERATIONAL FUNDAMENTALS

The gas turbine compressor takes air, compresses it, adds fuel, ignites the mixture, and directs the expanded gas against a turbine. A large mass of air is required by the gas turbine engine. The inlet must supply as much as ten times the amount of air required by a reciprocating engine. The air must reach the compressor in a smooth flow free from turbulence.

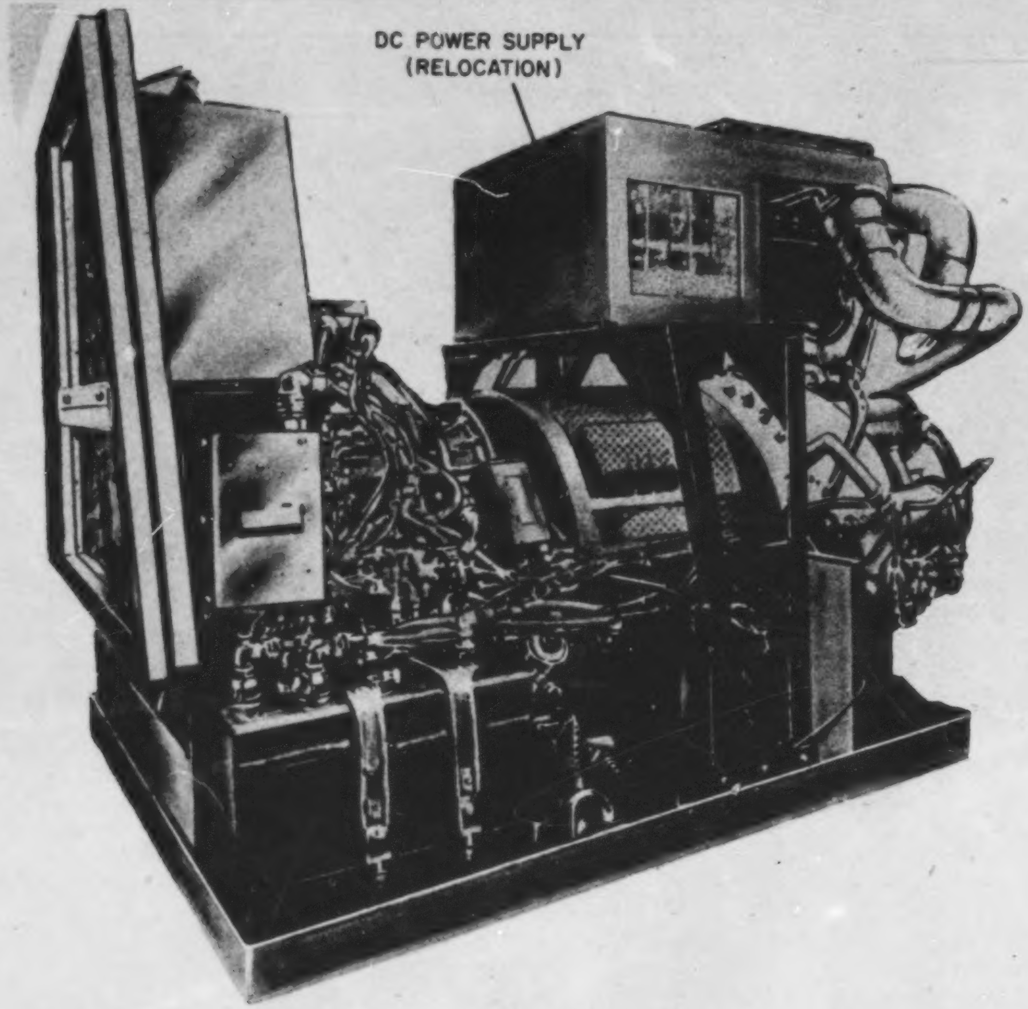
The compressor has as its function to increase the energy of the air received from the entrance duct and then discharge it to the combustion chamber in the quantity and at the pressure desired. The power to drive the compressor is provided by the turbine. The turbine and compressor units and their connecting shafts comprise the rotor assembly. The rotor assembly is the only major moving part in the gas turbine. Because its motion is entirely rotary, operation is inherently smooth. The compressed air now goes to the combustion chamber.

The combustion chamber serves to contain the combustion process which raises the temperature of the air passing through the engine. The combustion process injects fuel into the compressed air and ignites the mixture. This process releases the kinetic energy contained in the fuel-air mixture. The amount of fuel which may be burned is limited by the maximum temperature that can be tolerated by the turbine. This limitation may cause the ratio of air to fuel by weight to be less than 50 to 1. Fuel and air in this ratio will not burn if uniformly mixed; therefore, the combustion chamber is built so that only a small portion of the incoming air can contact the fuel spray. At the ignition point this portion of the mixture is within the combustible range. From this point the remaining air joins the burning mixture. The joining air receives some of the heat from the burning mixture and in so doing lowers the


MUFFLER ASSEMBLY
BLEED AIR OUTLET
CABLE STOWAGE ENCLOSURE
CONTROL PANEL ASSEMBLY
STRUCTURE ASSEMBLY
BASE ASSEMBLY
BLEED AIR DUCT STOWAGE
FORWARD AND AFT ENCLOSURE (HINGED)
FUEL TANK

213.17

Figure 12-5.–Model NCPP-105 compressor power unit.



213.18

Figure 12-6.—NCPP-105 flyaway assembly.

temperature of the gases exiting from the combustion chamber to a value safe for turbine operation.

The turbine receives the heated gases and transforms the energy of the burned gases to shaft power that drives the compressor and accessories. The heat causes the compressed air to expand. The only outlet from the combustion chamber is to the turbine. In its rush to escape, the gases build up enough velocity to turn the turbine when coming in contact with the turbine blades. The turbine and compressor are connected by a common shaft. The accessory section operates by a gear reduction drive connected to the front of the compressor shaft.

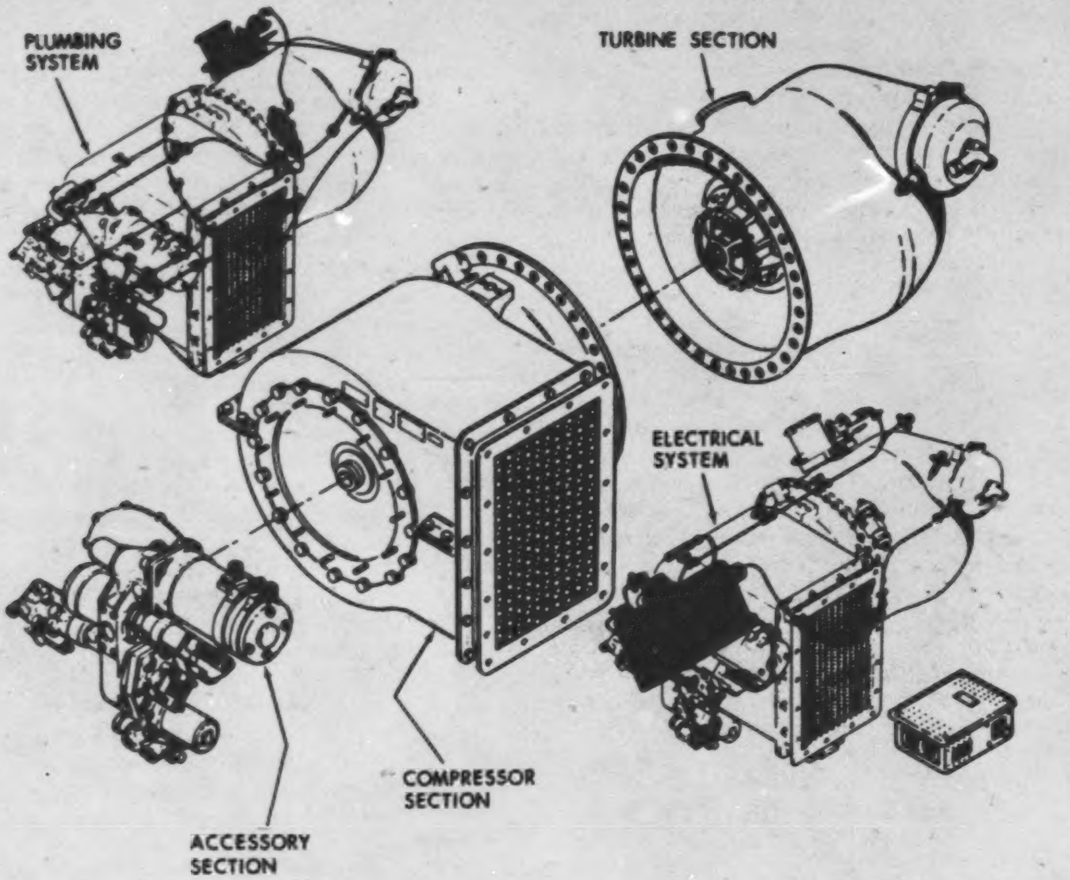
The compressed air is drawn off from the compressor section for use as pneumatic air. If all the air was routed to the turbine from the compressor, the turbine would produce more power than is needed to operate the compressor and accessories. Therefore, the amount taken for pneumatic equipment operation does not reduce the desired output of the engine. In a jet engine used in aircraft, where pneumatic air is not bled off, this excess energy is used for propulsion.

MAJOR COMPONENTS

The gas turbine engine, which is normally referred to as a unit, consists of a two-stage centrifugal compressor directly coupled to a radial inward-flow turbine wheel. Compressed air is obtained as bleed-air from the second stage of the compressor, which also supplies air to support fuel combustion in the turbine section. The unit is composed of three main sections—accessory, compressor, and power turbine. (See fig. 12-7.)

ACCESSORY SECTION

The accessory section is designed as a separate assembly and consists of a gear reduction drive coupled directly to the compressor shaft through a special type of drive



227.70

Figure 12-7.—Gas turbine compressor, major sections.

shaft. The accessory housing mounts and provides drives for the following accessories:

1. Starter.
2. Centrifugal switch.
3. Oil pump assembly.
4. Generator.
5. Fuel accessory assembly. (Fuel pump and control unit.)

COMPRESSOR SECTION

This section provides a source of compressed air for combustion and pneumatic power in the form of bleed air.

The ambient air is moved by the first and second stage impellers and is directed through diffusers which are mounted directly after the impellers. Compression is accomplished by the diffusers due to their divergent shape.

The impellers are mounted on a common shaft, the ends of which are splined internally to receive the drive shafts which connect the compressor to the accessory drive shaft and connect the turbine to the compressor.

POWER TURBINE SECTION

The turbine section is the power section which provides driving power for the entire unit. The major parts of this section are the turbine wheel, combustion chamber assembly, and nozzle assembly. Air, which has been taken into the compressor, is routed to the combustion chamber section where it is mixed with fuel and ignited. As the fuel-air mixture is burned, the gases expand rapidly, increasing the velocity of the gas as it is exhausted to the rear through the nozzle assembly. From the nozzle assembly these hot gases are directed onto the blades of the turbine wheel, turning the turbine at a very high speed. In turn, the turbine drives the compressor and the accessory drive assembly.

OPERATIONAL SAFETY PRECAUTIONS

In the operation of any gas turbine compressor unit, the ASM must first become completely familiar with the proper operating procedures. No one should attempt to operate these equipments until he has had an operational checkout by a qualified and authorized operator. The actual operation of gas turbine compressors is simple; however, they are powerful pieces of equipment and must be treated accordingly. The following safety precautions must be strictly enforced to prevent possible personnel injury or equipment destruction:

1. All personnel must remain clear of the compressor inlet. Although the turbine engine of the unit is small, as compared to the engine in an aircraft, it is very dangerous and consumes great quantities of air.

All personnel are aware of the destruction caused to an aircraft jet engine when a foreign object is ingested. Remember, the gas turbine compressor likewise will be destroyed, or seriously damaged, if the inlet area is not kept clear of foreign objects. Never carry loose articles such as pencils or oil wiping cloths in the pockets when working near operating units. Always inspect the entire area around the equipment (before starting the unit) to make sure no loose gear or debris will be pulled into the compressor.

2. The exhaust gas from this equipment is exactly like that of the engine in an aircraft–HOT–and exits from the unit at a terrific velocity. Therefore, personnel must avoid this area and make sure that the exhaust is not directed onto anything which the heat or the velocity of these gases would damage. A tragic fire in the carrier Enterprise was started by the exhaust from one of these units. ALWAYS BE CERTAIN that the exhaust is no closer than the prescribed distance from ANY object.

3. Another danger which lurks hidden in equipment of this type may not be quite as evident as the two previously discussed. This danger is in the area of the plane-of-rotation of the high-speed compressor and turbine assemblies. There have been times when a turbine blade has been sheared off and thrown out of the turbine. At the speeds which the turbine turns, the blades become like rifle bullets. Usually these areas are marked clearly

with red painted stripes. Never stand in the plane of rotation whether marked or not.

4. Always wear sound attenuators when working on or near this equipment while it is operating, since the noise level is very high and will cause loss of hearing. The use of the sound attenuators cannot be overstressed. Remember, a loss of hearing due to the high-frequency component of the noise generated by this equipment can and often does cause permanent damage to the auditory system.

FUNCTIONAL SYSTEMS

Before the ASM attempts to operate a gas turbine unit, he should have a knowledge of the different systems, and the function performed by each. In the gas turbine unit there are four main functional systems which are listed as follows:

1. Air system.
2. Fuel system.
3. Lubrication system.
4. Electrical system.

In the following paragraphs each of these systems is described briefly.

AIR SYSTEM

See figure 12-8. Rotation of the compressor creates a low-pressure area at the inlet side of the unit. This draws air through the oil cooler into the first stage compressor plenum chamber (air supply chamber). Note that the first stage of the compressor is constructed with a dual-entry; this is necessary to provide the large volume of air that is required for engine combustion and cooling and for supplying pneumatic power. As air is drawn into the first stage of the compressor, tremendous velocity is imparted to it by the first stage impeller. The air is then directed into the first stage diffuser where it is slowed down and its pressure increased (first stage compression) to approximately 18 psi. It is then directed through interstage ducts into the second stage of the compressor, and tremendous velocity is again imparted to it by the second stage impeller. It is then directed into the second stage diffuser where it is slowed down, and its pressure further increased (second stage compression) to approximately 37 psi. From the second stage compressor, the air is directed through a set of deswirl vanes where, as the term deswirl implies, the air is straightened out into a smooth flow as it enters the turbine plenum chamber. Approximately 75 percent of the air entering the turbine plenum chamber is used to support combustion and for combustion chamber cooling, while the remaining 25 percent is available as bleed-air for operation of pneumatic equipment. When no air is being bled from the engine, this 25 percent provides additional engine cooling, enabling the engine to operate at reduced temperature under no-load conditions.

Air enters the combustion chamber via small holes or perforations in the flame tube or liner, where it is combined with fuel and burned. The result of the burning of the fuel is the rapid expansion of the burning gases and creation of a high-velocity, high-energy, exhaust gas flow. This gas flow is collected in an assembly, referred to as the torus, and directed through a nozzle ring surrounding the turbine wheel and onto the blades of the turbine wheel at the proper angle to drive it. The high-velocity, high-energy exhaust gas flow drives the turbine (hence the term gas turbine) at a very high rate providing the power to drive the compressor and accessories and to support pneumatic loads. After passing through the turbine blades the exhaust gases (still hot) pass out the tailpipe to the atmosphere.

Fuel and Bleed-Air Control

(See fig. 12-9). This system functions automatically to maintain a near-constant turbine operating speed under varying conditions of load and to control the amount of bleed-air supplied by the engine. The system consists of electromechanical and pneumatic components with connecting plumbing and wiring. The principal components of the system are a fuel pump and control unit, an acceleration stabilizer and adjustable orifice assembly, a fuel atomizer assembly, an acceleration control

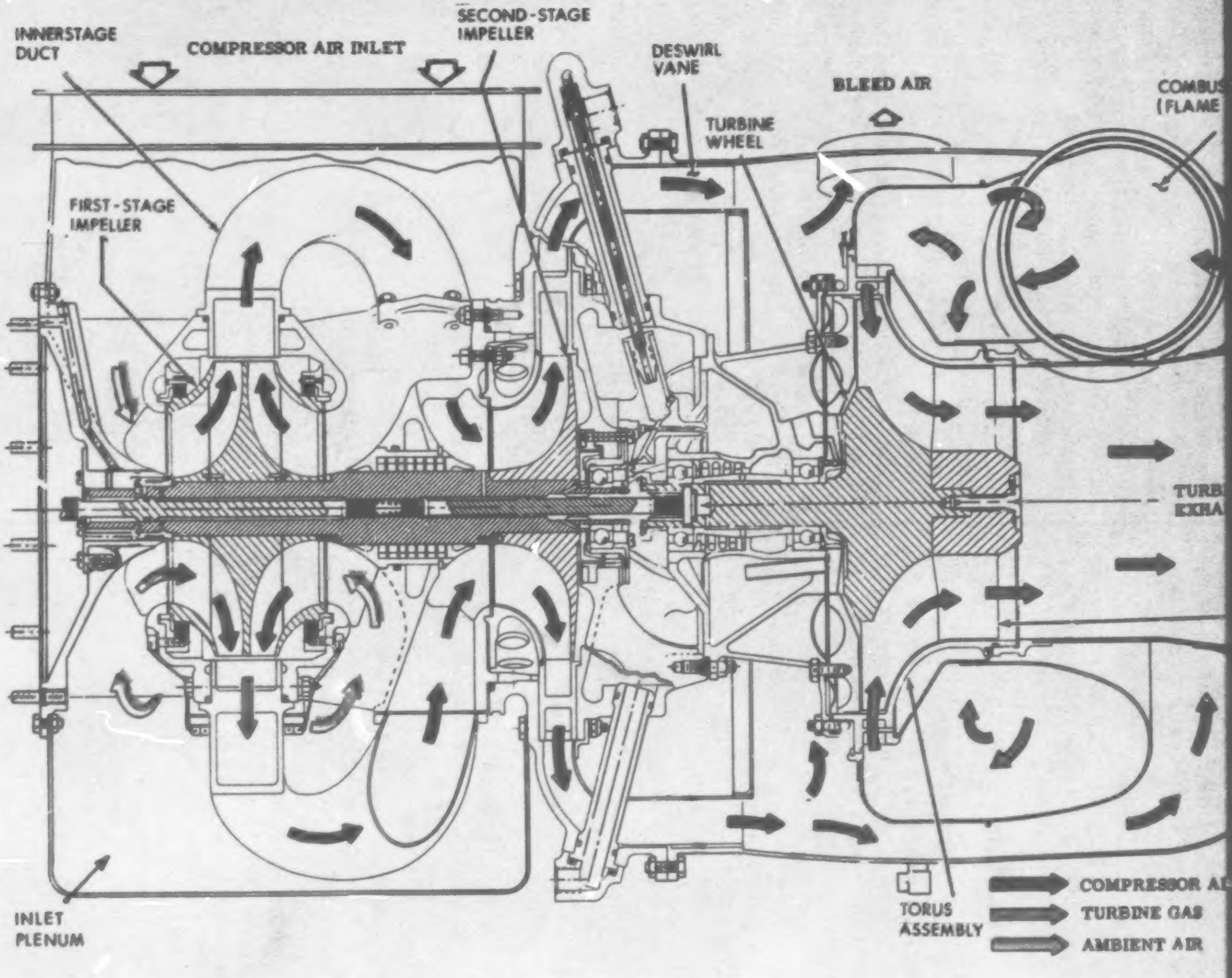
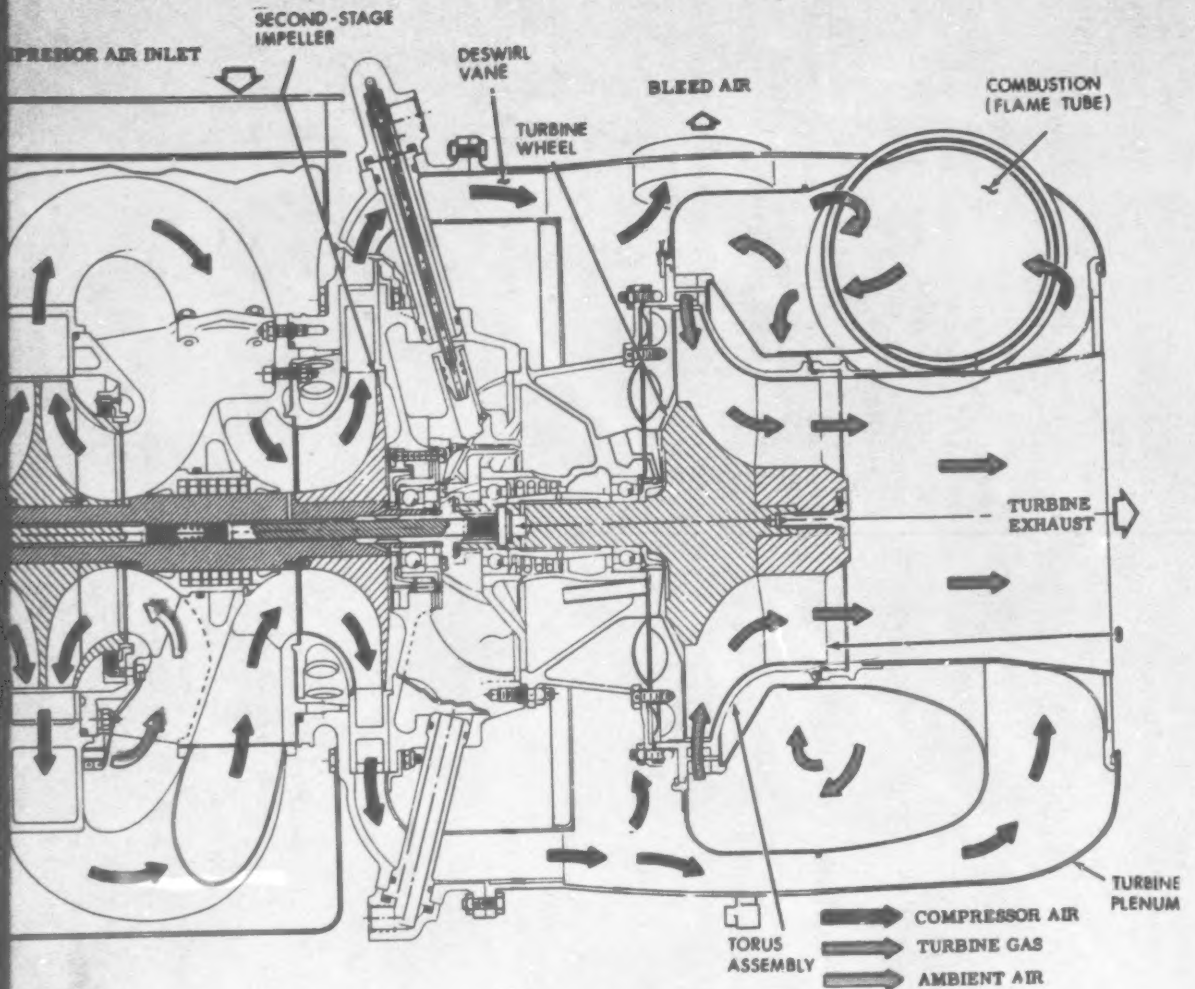
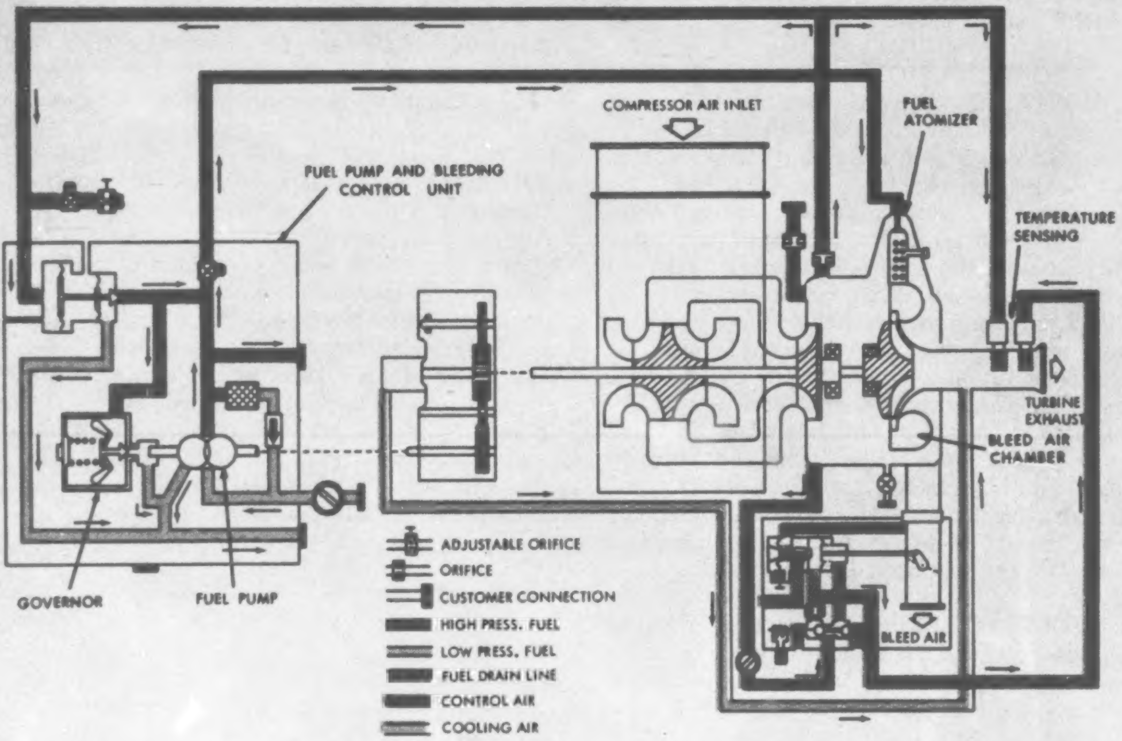

INNERSTAGE DUCT
COMPRESSOR AIR INLET
SECOND-STAGE IMPELLER
DESWIRL VANE
BLEED AIR
TURBINE WHEEL
COMBUS
(FLAME
FIRST-STAGE IMPELLER
TURB
EXHA
INLET PLENUM
TORUS ASSEMBLY
COMPRESSOR AI
TURBINE GAS
AMBIENT AIR

Figure 12-8.—Airflow through compressor and turbine.


PRESSOR AIR INLET
SECOND-STAGE IMPELLER
DESWIRL VANE
TURBINE WHEEL
BLEED AIR
COMBUSTION (FLAME TUBE)
TURBINE EXHAUST
TURBINE PLENUM
TORUS ASSEMBLY
COMPRESSOR AIR
TURBINE GAS
AMBIENT AIR

227.71

Figure 12-8.—Airflow through compressor and turbine.


COMPRESSOR AIR INLET
FUEL ATOMIZER
FUEL PUMP AND BLEEDING CONTROL UNIT
TEMPERATURE SENSING
TURBINE EXHAUST
BLEED AIR CHAMBER
BLEED AIR
GOVERNOR
FUEL PUMP
ADJUSTABLE ORIFICE
ORIFICE
CUSTOMER CONNECTION
HIGH PRESS. FUEL
LOW PRESS. FUEL
FUEL DRAIN LINE
CONTROL AIR
COOLING AIR

227.72

Figure 12-9.—Fuel and bleed-air control system.

thermostat, an unloading air shutoff (load) valve, and a bleed-load control thermostat.

FUEL PUMP AND CONTROL UNIT.–The fuel pump and control unit incorporates the fuel pump, acceleration limiter (bypass) valve, a flyweight-type (mechanical) governor and a fuel solenoid valve.

The acceleration limiter valve consists of a check valve actuated by two diaphragms–one controlled by fuel pressure and the other by a combination of spring pressure and compressor discharge (control) air pressure. It is called a bypass valve because it is designed to control fuel flow to the atomizer assembly by bypassing a portion of the fuel delivered by the fuel pump back to the fuel tank in relation to compressor discharge air pressure. As engine rpm increases and compressor discharge air pressure increases, less fuel is bypassed and more is delivered to the atomizer assembly. The acceleration limiter valve controls fuel flow during starting and acceleration up to approximately 95 percent of governed engine rpm.

The mechanical governor begins to function as engine rpm reaches approximately 95 percent. Enough centrifugal force is applied to the flyweights at this point to allow the governor to begin bypassing fuel, in conjunction with the acceleration limiter valve. The combined bypass action of the acceleration limiter valve and the governor allow just enough fuel to reach the atomizer assembly to maintain governed engine rpm.

The fuel solenoid valve is of the normally closed type. It admits or shuts off fuel flow to the atomizer assembly in response to electrical control system operation.

ACCELERATION STABILIZER AND ADJUSTABLE ORIFICE ASSEMBLY.–The acceleration stabilizer and adjustable orifice assembly consists of a normally open solenoid valve and an adjustable air bleed installed in the control air line between the acceleration limiter valve and the acceleration control thermostat. Its purpose is to control and stabilize the rate of acceleration by bleeding control air pressure off the acceleration limiter valve. Bleeding off a portion of the air pressure from the acceleration limiter valve causes the valve to bypass more fuel, decreasing the rate of acceleration. The solenoid is energized during starting (up to 35 percent of governed engine rpm) and when the load switch is actuated, causing the acceleration limiter valve to close and bypass no fuel. This provides the increased fuel flow required at these times to support engine operation.

FUEL ATOMIZER ASSEMBLY.–The fuel atomizer assembly is a dual orifice type and is mounted on the combustion chamber cap assembly. A flow-divider valve directs all fuel at low pressure to the small orifice which provides proper atomization of the fuel during starting. As engine rpm increases and fuel pressure increases, the flow divider valve actuates to permit combined flow to both orifices.

ACCELERATION CONTROL THERMOSTAT.–The acceleration control thermostat is mounted in the engine tailpipe. It consists of a spring-loaded-closed, ball check valve, actuated by exhaust gas temperature (EGT). It is connected to the acceleration limiter valve by a control air line. The thermostat acts to override control of fuel flow by dumping all the control air pressure from the acceleration limiter valve if the EGT exceeds a specified limit during acceleration.

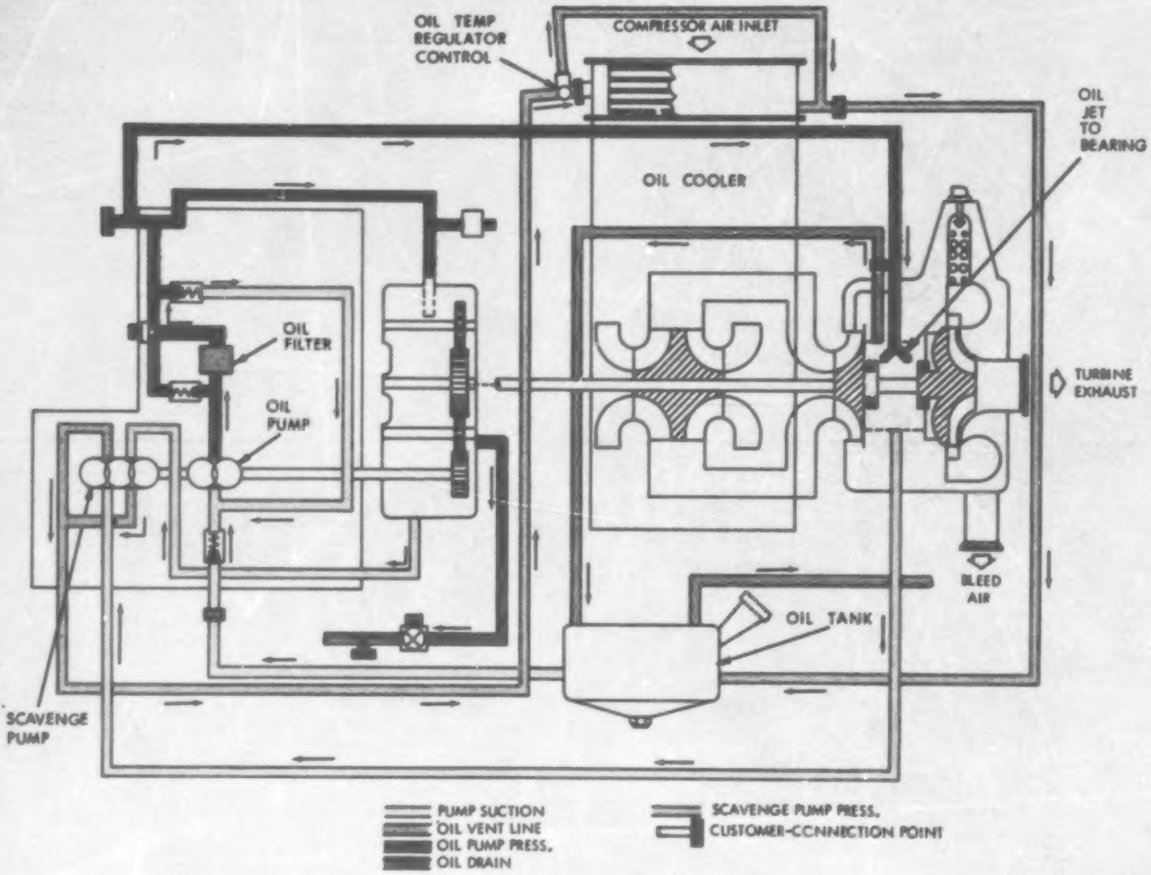
UNLOADING AIR SHUTOFF VALVE.–The unloading air shutoff (load) valve assembly consists of a normally closed solenoid valve, a normally closed butterfly valve, and two diaphragms. It functions to control the amount of air that is bled from the engine in relation to EGT. If too much air is being bled off (over-loading), action of the bleed-load control thermostat allows the butterfly valve to close sufficiently to regulate bleed-air flow without causing engine shutdown or loss of engine speed.

BLEED-LOAD CONTROL THERMOSTAT.–The bleed-load control thermostat is mounted in the engine tailpipe. It has the same construction as the acceleration control thermostat and is connected to the load valve by a control air line. It functions to control the bleed-load in relation to EGT. At a specified temperature, the thermostat valve opens and bleeds control air pressure from the actuator diaphragm of the load valve. This reduction in control air pressure allows the butterfly valve to modulate, thereby maintaining the maximum permissible bleed-load on the engine and preventing overloading.

LUBRICATION SYSTEM

The lubrication system is very simple; but, because of the temperatures and rpm at which the unit operates, positive feed oil pressure for lubrication and cooling must be provided. The system includes a pressure and scavenge pump, an oil filter, an oil temperature regulator, an oil cooler, and an oil tank. (See fig. 12-10.) Oil under pressure is supplied to all gears, shafts, and bearings. After the oil has been used, it collects in the common sump between the compressor and turbine assemblies and in the sump of the accessory section and is then returned, by the scavenge pump, to the oil tank.

If the temperature of the oil is such that it requires cooling, it is routed through the oil cooler. Cooling is accomplished by compressor inlet air flowing around the tubes of the oil cooler. If the temperature of the oil is not great enough to require cooling, a bypass valve in the temperature regulator routes the oil directly to the oil tank, where it is again pumped through the engine. The unit is provided with an oil pressure actuated switch which prevents starting of the engine until oil pressure builds up sufficiently to close the switch. Also, if oil pressure is lost during operation, this switch will function to shut down the engine. Sometimes,


OIL TEMP REGULATOR CONTROL
COMPRESSOR AIR INLET
OIL JET TO BEARING
OIL COOLER
OIL FILTER
OIL PUMP
TURBINE EXHAUST
BLEED AIR
OIL TANK
SCAVENGE PUMP
PUMP SUCTION
OIL VENT LINE
OIL PUMP PRESS.
OIL DRAIN
SCAVENGE PUMP PRESS.
CUSTOMER-CONNECTION POINT

227.73

Figure 12-10.—Lubrication system.

oil pump will require priming to provide oil pressure at time of starting.

ELECTRICAL SYSTEM

The electrical system provides the means for starting, operating, and stopping the engine. It is a 26±2-volt dc system which may be operated from a battery or an external power source, such as a mobile electric powerplant.

The electrical system has two groups of components–engine mounted and enclosure mounted. The engine group is the same for all installations, but the enclosure group will vary as to type of components and circuitry. A typical electrical system schematic is shown in figure 12-11.

The components of the engine group are the electrical control box, ignition system, generator, starter, centrifugal switch assembly, oil drain solenoid valve, fuel solenoid valve, acceleration stabilizer solenoid valve, and the load control solenoid valve.

ELECTRICAL CONTROL BOX.–Electrical control of the engine is maintained through the electrical box. (See fig. 12-12.) It houses the starter and ignition holding relay, fuel holding

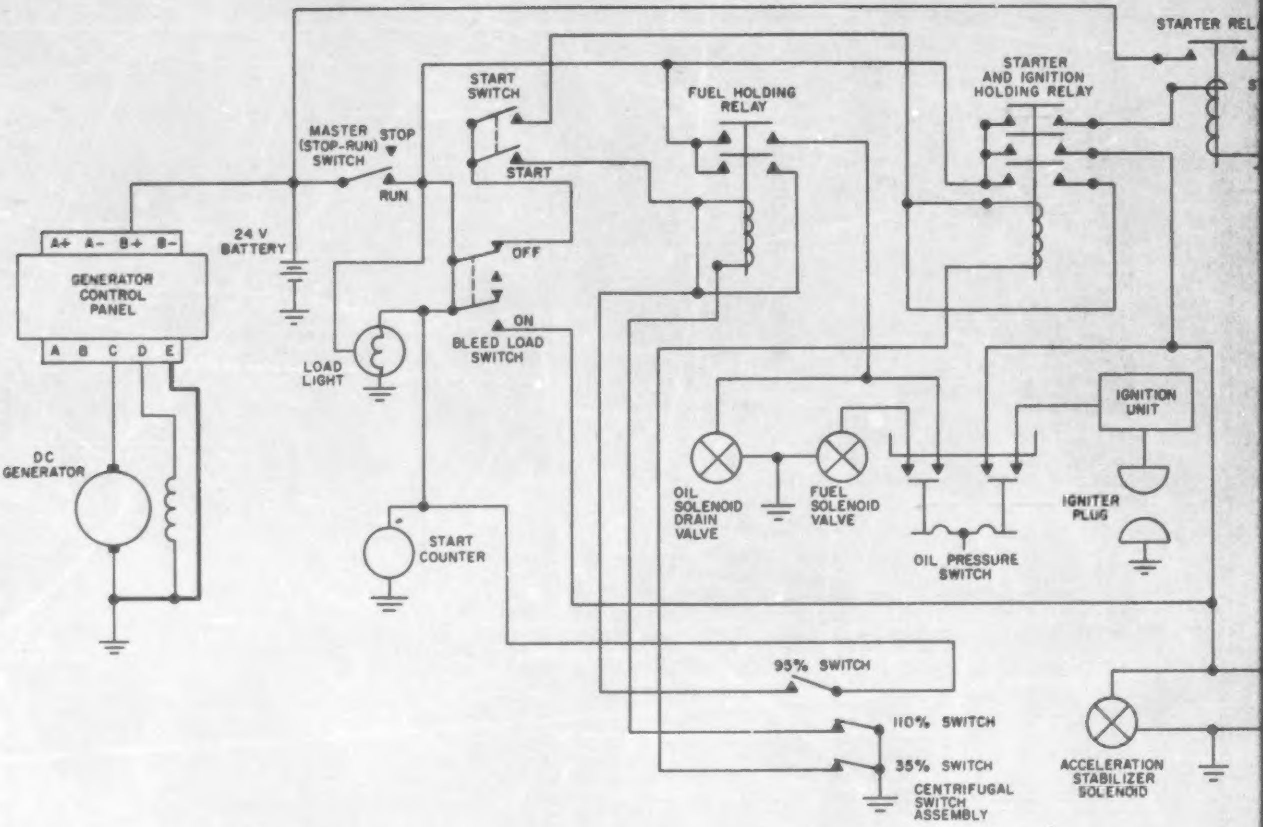
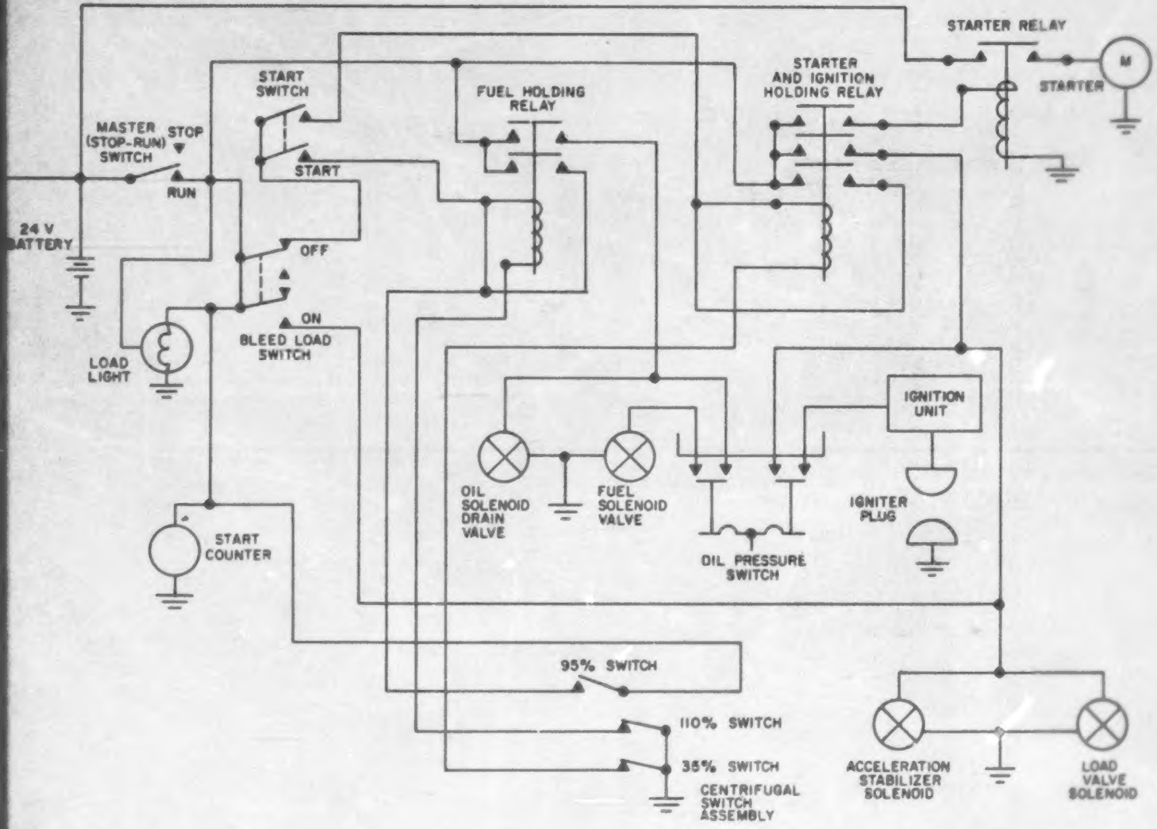
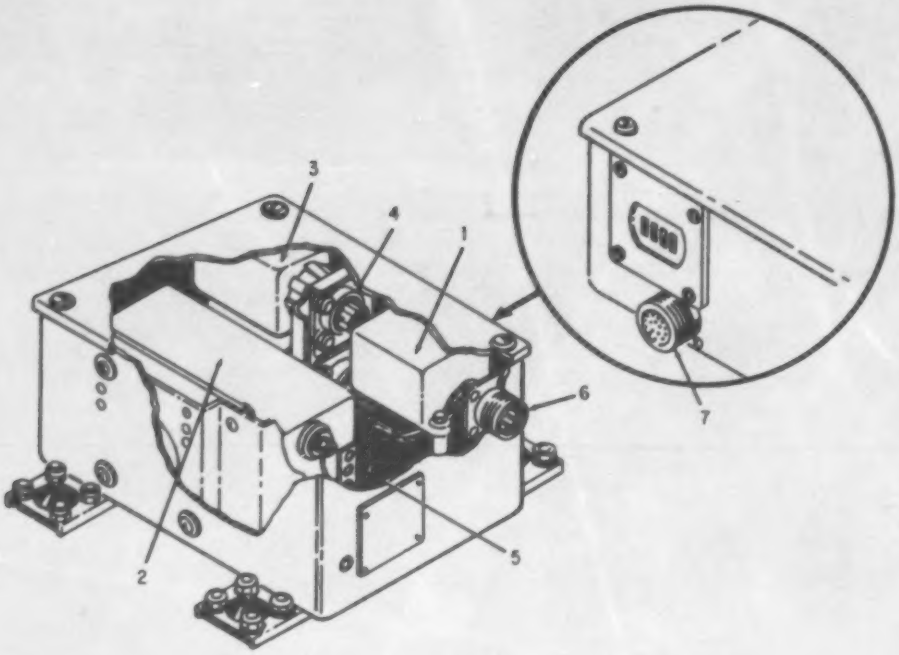

STARTER REL
START SWITCH
FUEL HOLDING RELAY
STARTER AND IGNITION HOLDING RELAY
MASTER (STOP-RUN) SWITCH
STOP
RUN
START
A+ A- B+ B-
GENERATOR CONTROL PANEL
A B C D E
24 V BATTERY
OFF
ON
BLEED LOAD SWITCH
LOAD LIGHT
DC GENERATOR
START COUNTER
IGNITION UNIT
OIL SOLENOID DRAIN VALVE
FUEL SOLENOID VALVE
OIL PRESSURE SWITCH
IGNITER PLUG
95% SWITCH
110% SWITCH
35% SWITCH
CENTRIFUGAL SWITCH ASSEMBLY
ACCELERATION STABILIZER SOLENOID

Figure 12-11.—Electrical system.


STARTER RELAY
M
STARTER
STARTER
AND IGNITION
HOLDING RELAY
FUEL HOLDING
RELAY
START
SWITCH
MASTER
(STOP-RUN)
SWITCH
STOP
START
RUN
24 V
BATTERY
OFF
ON
BLEED LOAD
SWITCH
LOAD
LIGHT
IGNITION
UNIT
OIL
SOLENOID
DRAIN
VALVE
FUEL
SOLENOID
VALVE
IGNITER
PLUG
START
COUNTER
OIL PRESSURE
SWITCH
95% SWITCH
110% SWITCH
35% SWITCH
CENTRIFUGAL
SWITCH
ASSEMBLY
ACCELERATION
STABILIZER
SOLENOID
LOAD
VALVE
SOLENOID

226.175

Figure 12-11.—Electrical system.



225.176

Figure 12-12.–Electrical control box.

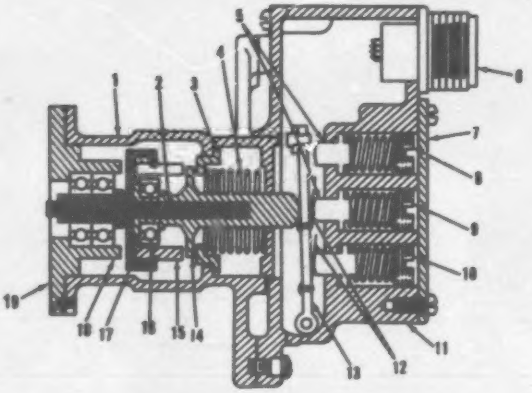
relay, ignition unit, and the start counter. The starter and ignition holding relay and the fuel holding relay, when energized, provide power to the circuits they control and also to their own coils for a holding action. The ignition unit provides the high-tension current to the igniter plug.

IGNITION.–The gas turbine engine ignition system is very simple in construction and operation. The entire system consists of the igniter (spark unit) located in the combustion chamber, a section of high-tension ignition lead, and the ignition unit located in the electrical control box. The ignition unit provides the high-energy voltage source. This is accomplished by a step-up transformer which charges internal storage capacitors. The storage capacitors are then discharged across a booster coil arrangement, and the high voltage is applied to the igniter. After the engine has started and a flame is established in the combustion chamber, the ignition system is deenergized, since burning is constant once a successful start has been accomplished.

NOTE: The voltage to the igniter is dangerously high (near 40,000 volts); therefore, caution must be observed when maintenance is performed on the ignition system. Always make certain that the capacitors are fully discharged before removing or checking components of the ignition system.

GENERATOR AND STARTER ASSEMBLIES.–The generator, driven by the accessory drive gear section, is a continuous-duty unit rated at 12 amperes and 28 volts. Cooling of the generator is provided by air drawn through cooling inlet holes in the generator housing through the generator, into a cooling outlet tube, and into the turbine exhaust. Control of the generator and the circuits associated with it is the function of the voltage regulator and reverse current relay. These units and a noise filter are located in the generator control panel. The starter unit operates on a 24- to 28-volt power supply; power for operation of the starter may be provided by a battery or may be supplied from an alternate external 28-volt source. The starter is provided with a friction and inertia type of clutch mechanism which allows automatic initial engagement, and disengagement is accomplished when the speed of the accessory drive is exceeded. Starter motor current is cut off at 35 percent of engine speed.

CENTRIFUGAL SWITCH ASSEMBLY.–The centrifugal switch assembly (fig. 12-13), through the operation of a set of flyweights, controls the sequence of operation of the electrical system. As the flyweights are caused to move outward by centrifugal force, three switches are actuated by an actuating lever. The first to operate is the 35-percent switch which deenergizes the starter and ignition holding relay. The second to operate is the 95-percent switch which energizes the ready-to-load light, load switch circuit, and the start counter. The last switch to operate, the 110 percent switch, operates at from 105 to 110 percent and is a safety device to protect the engine from overspeed. When this switch operates, the fuel holding relay is deenergized and the engine stops.



1. Housing.
2. Centrifugal switch shaft.
3. Spring sliding retainer.
4. Compression spring.
5. Push rod.
6. Receptacle.
7. Access plate.
8. Adjusting screw.
9. Adjusting screw.
10. Adjusting screw.
11. Switch cover.
12. Leaf spring.
13. Switch actuating lever.
14. Lever actuator.
15. Governor flyweight.
16. Ball bearing.
17. Fulcrum flyweights.
18. Overspeed switch bearing carrier.
19. Mounting flange.

227.177

Figure 12-13.—Centrifugal switch assembly.

The principal components of the enclosure group are a starter relay, generator control panel, and an engine control panel. The engine control panel provides the operating controls and instruments for monitoring engine operation.

Preoperational Inspection

The Preoperational Maintenance Requirements Cards require a thorough visual inspection of the unit, and it should be remembered that these are the minimum requirements prior to starting. All accessories, wiring, tubing, ducts, and fittings are inspected for security and mounting. Check the entire unit for evidence of fuel or oil leakage; if leakage is detected, do not attempt a start, as a serious fire may result.

The compressor intakes and the turbine exhaust ducts must be inspected for foreign material or other obstructions. Check for the proper oil level in the oil tank, replenish as required. Check for adequate fuel supply and for security of fillercaps and connections.

All instruments must be checked for zero or normal indication as appropriate, and for fogged or broken glass. On indicators which have range-marks, check for the marks being in the correct location. The bleed air connection is checked for obstructions, and the bleed airhose is inspected for torn shielding and for holes; the hose clamps are also checked for security at this time.

The battery must be inspected for security of the clamp assembly and terminals. Connect the battery and check for a minimum reading of 24 volts. (Inspection of the battery electrolyte and specific gravity is a special inspection performed at 7-day intervals.) A fire extinguisher must always be available if the unit is to be started. In the case of the trailer-mounted enclosure, the fire extinguisher is mounted in a special mounting and must be included in the preoperational inspection. The fire extinguisher is checked for proper mounting and for security of the seal.

Starting

After the preliminary checks and inspections have been completed, the following steps are performed: (1) manual fuel valve–OPEN; (2) stop-run switch–RUN; and (3) bleed-load switch–OFF. Then momentarily press the start switch to the START position.

CAUTION: If difficulty is encountered in starting, do not exceed the duty cycle of the starter–1 minute ON, 4 minutes OFF.

When a new or overhauled unit is started, or if the oil lines have been disconnected, the oil primer button must be pressed as the unit is started; release the button when the unit lights off. Normal governed speed should be reached within 15 to 20 seconds. When 95 percent governed speed is reached, the load light should glow and the load may then be applied if desired by placing the bleed-load switch in the ON position.

Shutdown

EMERGENCY.–Stop the engine immediately by depressing the stop-run switch to the STOP position if any of the following conditions are observed.

1. No oil pressure within 10 seconds after the start circuit is energized.
2. If the turbine discharge temperature exceeds 677° C (1,250° F) for a period greater than 5 seconds; or if the temperature exceeds 649° C (1,200° F) continuously under any operating condition.
3. If ignition failure occurs (flame-out), to prevent fuel accumulation in the turbine section.

NORMAL.–The unit requires a 1 minute operating period under no-load prior to stopping in order to allow for a gradual cooling off. After the 1-minute cooling-off period, place the stop-run switch in the STOP position. When the turbine stops turning turn the manual fuel shutoff valve OFF. The unit should be checked visually for any discrepancies and fuel and oil levels.

If any discrepancies exist, take the necessary steps to have them corrected so the unit will be ready for use when it is needed again. Disconnect and stow the air hose, etc., disconnect the battery, and secure the access panels.

NOTE: The equipment manual for the particular gas turbine being operated should be consulted for proper starting and shutdown procedures.

SYSTEM OPERATION

(Refer to fig. 12-11.) With the master (stop-run) switch in the run position, power is available to the start switch, through the load switch in its OFF position, the test circuit of the load light, the contacts of the fuel holding relay, and the contacts of the starter and ignition holding relay. Depressing the momentary contact start switch energizes the coils of the fuel holding and the starter and ignition holding relays. The fuel holding relay energizes the oil solenoid drain valve, the fuel side of the oil pressure switch, the normally open 95-percent switch, and its own coil. Ground for the fuel holding relay coil is through the normally closed 110-percent switch. The starter and ignition holding relay energizes the starter relay, acceleration stabilizer solenoid, load valve solenoid, ignition side of the oil pressure switch, and its own coil. Ground for the starter and ignition holding relay is through the normally closed 35 percent swtich. The starter relay energizes the starter motor which begins rotating the engine. At about 5,000 rpm, rising oil pressure closes the oil pressure switch, energizing the fuel solenoid valve and the ignition unit. Combustion is initiated, and the engine begins to accelerate under the combined drives of the starter and combustion until approximately 15,000 rpm (35 percent) is reached. At this time the 35-percent switch opens the ground-circuit to the coil of the starter and ignition-holding relay, causing it to open. This action deenergizes the starter relay, ignition unit, acceleration stabilizer solenoid and the load valve solenoid. The engine continues to accelerate and as approximately 42,000 rpm (95 percent) is reached, the 95-percent switch closes, energizing the load light (indicating that a load may now be applied), start counter, and the circuit to the load switch. The engine is loaded by placing the load switch in the ON position. This energizes the load valve solenoid and the acceleration stabilizer solenoid. If at any time the engine speed reaches 105 to 110 percent, the 110-percent switch opens, opening the ground circuit to the coil of the fuel holding relay, causing it to open. The action deenergizes the fuel solenoid valve, and the bleed-load valve circuit. Fuel flow to the engine is stopped, the load valve colses, and the engine is shut down.

SYSTEM FUEL CONTROL

Fuel flow to the engine determines engine rpm, and turbine temperature, and must be accurately controlled. During starting and acceleration, fuel is controlled by the fuel pump and control unit, acceleration control thermostat, and fuel atomizer assembly. The pneumatic portion of the fuel pump and control unit functions during the starting cycle to increase fuel pressure in relation to the increase of compressor pressure by the amount of fuel allowed to bypass, thus increasing the pressure applied to the fuel atomizer assembly. If the turbine temperature exceeds the specified value during the start cycle, the acceleration control thermostat opens and allows more fuel to bypass, thereby reducing the pressure of the fuel applied to the fuel atomizer assembly.

The fuel atomizer assembly is constructed with a dual discharge orifice; this arrangement includes a valve called a flow-divider valve which remains closed at low pressure (starting pressures), and opens as acceleration increases, allowing an increase of fuel to flow at higher rpm. The correct amount of fuel is supplied to the engine and is properly atomized at all speeds.

GOVERNED OPERATION

After the engine has reached a steady state, this steady state condition is maintained from no-load to full-load (except when the engine is overloaded) by the fuel pump and control unit. The governor of the fuel pump and control unit automatically regulates the fuel flow to match the power demands placed upon the turbine wheel maintaining a substantially constant turbine wheel speed. This is done by sensing the speed of the turbine through the flyweights of the control unit. During underspeed condition, the governor restricts fuel bypass which increases the pressure applied to the fuel atomizer assembly which in turn increases turbine speed. To compensate for an overspeed condition, fuel flow is decreased by bypassing more fuel and reducing the pressure of the fuel applied to the atomizer assembly. A serious overspeed could damage the engine; thus, it is the function of the 110-percent switch to close the fuel solenoid shutoff valve and cut the supply of fuel off, stopping the engine when overspeed occurs.

MAINTENANCE

Maintenance as set forth in the Calendar Maintenance Requirements Cards is to be performed at an intermediate level maintenance activity. The reason is that this equipment is a precision unit that requires special tools and testing devices which are not available at the lower levels of maintenance. The areas where the work is performed have special requirements as to cleanliness and power availability. The determining factor which governs the intervals between maintenance performed is the number of engine starts.

At time of engine replacement, the crew will be required to operate a hoist or some type of chain fall when hoisting the unit out of its enclosure, placing it in a shipping container, and installing a new unit in the enclosure. There is no specific hoisting device included in the instructions given in the maintenance requirements cards; therefore, the crew leader will normally assume the responsibility for selecting a type of hoisting device that will allow this operation to be performed with maximum safety. Removal and installation of these units demand an alert crew; each step of the removal or installation procedure must be performed in strict accordance with the instructions provided in the appropriate manual or as outlined in the maintenance requirements cards for the type of unit being maintained.

The special lifting adapter, which is supplied with the unit, may not be replaced with a substitute. These adapters are made for use with the specific unit, and substitution can cause imbalance during hoisting, or may be the cause for the unit to be dropped, with possible injury to a crewmember, or damage to the unit.

CLEARANCES

Axial clearances in compressors and turbines as published in appropriate technical publications are a result of placement of shims and spacers when the unit is reassembled after overhaul or repair. The thickness of the shims and spacers is stated in the Maintenance Instructions Manual for the particular gas turbine compressor. Shims can be added or removed to increase or reduce the clearances to that desired. The radial clearances are also listed in the Maintenance Instructions Manual.

Another important check when assembling the rotating parts of the gas turbine compressor is the balance of the assembled parts. This is done on a standard balancing machine. The procedure is contained in the Maintenance Instructions Manual and is usually performed by a depot maintenance activity.

TROUBLESHOOTING

At the intermediate maintenance level, the ASM may expect to be a part of a troubleshooting/maintenance crew. This crew will probably consist of a senior AS and at least one each of the three service ratings (ASE, ASH, ASM). When a malfunctioning unit is received, a troubleshooting crew is assigned to locate the trouble, make the necessary repairs, and return the equipment to an operational status.

A guide to common engine malfunctions, their probable causes, and an appropriate remedy is provided in the maintenance section of the Maintenance Instructions Manual. Table 12-1 presents a section of the type of troubleshooting information that is found in the manual. The tables in the manual do not cover all of the possible malfunctions, but should be used as a guide when performing corrective maintenance.

In table 12-1, the appropriate portion of the maintenance section is referenced when specific step-by-step instructions are to be followed.

A useful tool in troubleshooting the gas turbine is the UPUA4-1 gas turbine engine analyzer. See figure 12-14. This analyzer is a portable unit with instruments which can measure speed, exhaust temperature, oil temperature, turbine driven ac generator frequency (GTCP 100 only), electrical component resistance and current, and dc and ac voltage of a gas turbine compressor. The analyzer's hydraulic and pneumatic system provides for measurement of turbine unit oil and fuel pressure, control air pressure, and for regulation of turbine unit control air.

The analyzer provides a lightweight (approximately 50 pounds) testing unit. This unit has an electrical system with associated meters and indicators and also a hydraulic and pneumatic system with associated gages and controls. The purpose of the testing unit is for checking and controlling the performance of gas turbine compressor units, gas turbine power units, combined compressor and power units, and their components.

The tachometer indicator has two dials for speed ranges of 0 to 2,500 and 2,500 to 5,000 rpm. A conversion chart attached to the analyzer cover door provides conversion factors for turbine unit gear ratios for determining turbine unit actual speed. For example, the GTC 85 has a ratio of tachometer rpm to gas turbine wheel rpm of 1 to 9.524. This means that an indication on the tachometer of 4,000 rpm represents 38,096 rpm of the gas turbine wheel.

A temperature indicator with a range of 0° to 1,800° indicates the turbine unit exhaust temperature. The oil temperature can be read on an indicator with a range of 0° to 150°C. The frequency reading for the turbine-driven ac

Table 12-1.—Troubleshooting information

Trouble	Probable cause	Remedy
Rate of acceleration too fast.	Fuel pump acceleration control bypass valve defective.	Replace fuel pump and control unit.
	Fuel pump governor defective.	Replace fuel pump and control unit.
	Acceleration and overtemperature control thermostat defective.	Block off thermostat. Restart unit, controlling temperature with speed control valve on analyzer. If operation normal, replace thermostat.
	Acceleration stabilizer and adjustment orifice defective.	Check for proper actuating. Replace if necessary.
Failure of unit to start, with start attempt not terminated by pressing stop switch at end of cycle.	Starter motor assembly failure.	Replace starter motor assembly. Check for malfunction that caused cutoff failure. Observe starter duty cycle limit.
	Centrifugal switch 35-percent switch defective, failing to cut off starter.	If starter and ignition lights do not go out above 35 percent, replace centrifugal switch.
Excessive turbine temperature on start.	Acceleration and overtemperature control thermostat defective.	Replace acceleration and overtemperature control thermostat.
	Fuel pump acceleration control bypass valve stuck.	Replace fuel pump and control unit.
Smoke emitted for short time after start.	Excessive oil in system or oil tank.	Drain oil to proper level.
	Oil pump check valve leaking.	Check and clean check valve.
	Scavenge oil pump defective.	Replace oil pump assembly.
Excessive oil smoke from unit or tank vent during operation.	Accessory case vent plug loose.	Visually check.
	Oil Cooler leak.	Visually check.
	O-ring packing failure on oil jet and vent tubes; oil drain and vent tube; turbine end drain connection.	Remove parts and check O-ring packing.
	Oil drain solenoid valve defective.	Check valve coil for normal resistance on ohmmeter. Replace if abnormal.
	Turbine plenum drain check valve sticking closed.	Clean or replace check valve.

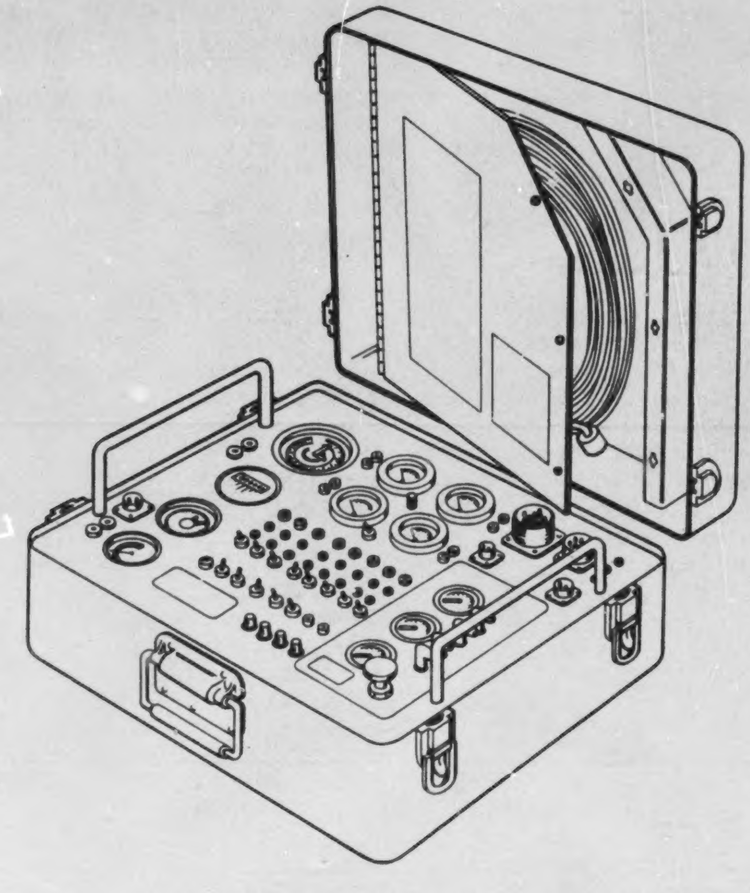


Figure 12-14.–Gas turbine engine analyzer assembly. 224.136.1

generator is indicated on a frequency meter with a range of 380 to 420 Hz. An ohmmeter provides resistance readings for turbine unit components. A dc ammeter and voltmeter provides current readings for turbine unit electrical components. An ac voltmeter provides voltage readings for the turbine-driven alternator. Each indicator is provided with two jacks to permit connection to the appropriate circuit in the turbine unit. Since the analyzer is a sensitive monitoring device, care must be taken to operate it properly. Be sure to study the turbine unit maintenance manual before using the tester. Make certain you are thoroughly trained in the correct use of the analyzer before using it on your own. This tester requires periodic calibration to ensure that it is operating properly. Be sure to check the calibration sticker for currency before testing the unit. This step is frequently overlooked.

GENERAL CLEANING PROCEDURES

Electrical parts may be cleaned with a soft cloth dampened in solvent of the type specified only. When using a solvent, the technician must be sure to keep the area well ventilated and avoid breathing the fumes. He must also keep away from flames. A clean, dry, soft-bristle brush may also be used. Metal parts and tube assemblies may be cleaned by dipping the part in solvent when required, then drying thoroughly with clean compressed air. Air, fuel, or oil passages in removed components may be blown clean with compressed air, but care must be exercised to direct the airblast away from personnel and equipment.

Removal of hard carbon deposits from gas turbine unit components may be accomplished by using one of the approved decarbonizing agents. Consult the appropriate maintenance instructions for removal of carbon deposits. Use of sandpaper, wire bristle brush, or scrapping tools is strictly prohibited. When considerable time will elapse before use of the parts cleaned, they should be placed in clear plastic bags to prevent corrosion and contamination by dirt or dust.

MINOR REPAIR AND ADJUSTMENT

Most repairs to the gas turbine compressor involve the removal of major components of the unit. This consists principally of the disconnection of the electrical and tubing connectors, removal of attached hardware, and withdrawing the component from the unit. All removals should be accomplished in keeping with good shop practice.

Some parts require only minor repair which consists of inspection, repair, and cleaning of faulty components. The next paragraphs give instructions for minor repairs and adjustments to the GTC 85 gas turbine compressor.

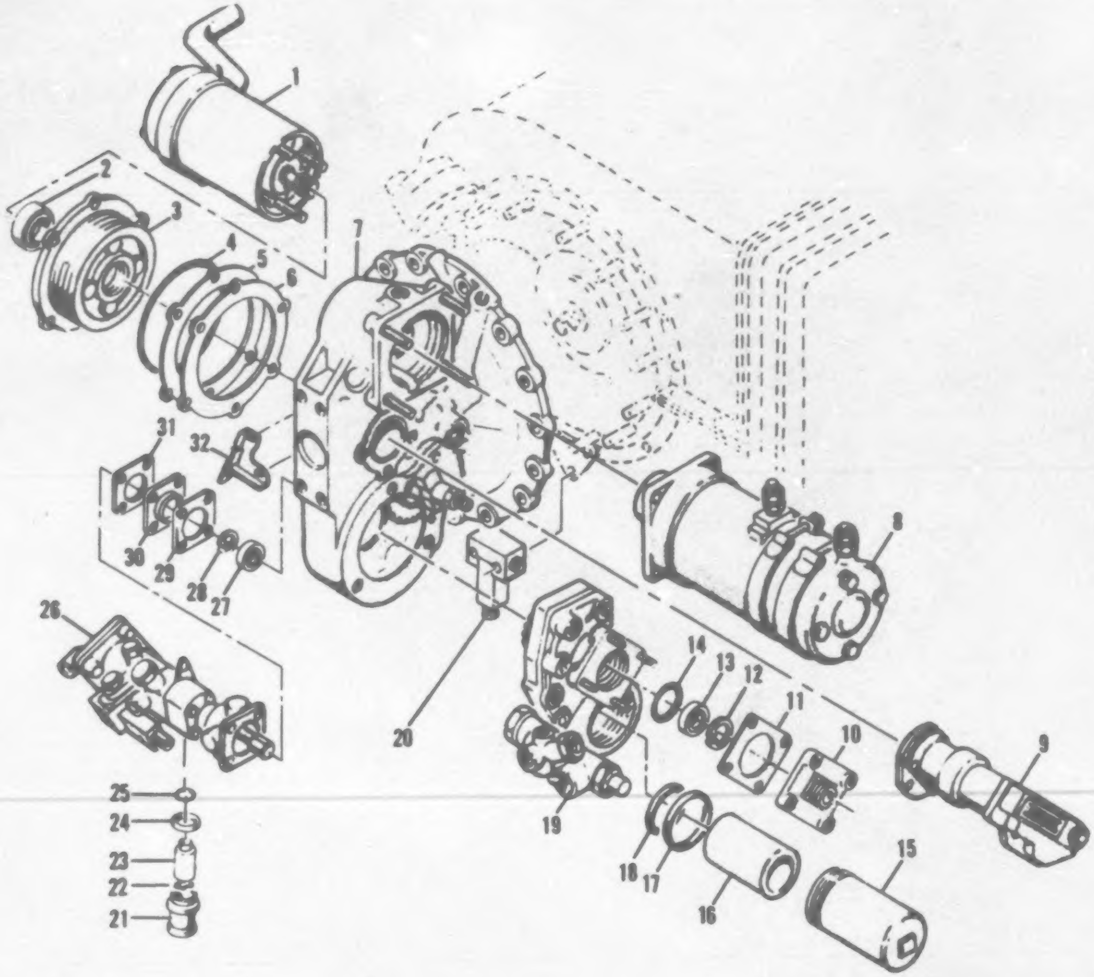
The replacement of the accessory assembly main drive gear bearing carrier seal (2, fig. 12-15) requires removal of the generator and the screws and washers attaching the carrier assembly. To hold the gears in place, press your thumb against the end of the main drive gear shaft and remove the carrier assembly and seal. When removing shims and packing, record the thickness and number of shims for reassembly. Press the old seal off the carrier assembly; press the new seal on the carrier assembly. Reassemble, making sure the same thickness of shims are used.

The fuel filter element (23, fig. 12-15) may be removed by unthreading the filter cap from the body of the fuel pump and control unit and removing the packing, filter spring, filter element, and filter guide. Clean the filter cap and filter guide in solvent and dry thoroughly. Inspect the element carefully for any indication of damage or imperfection and replace if necessary.

To clean the fuel atomizer assembly (fig. 12-9 soak it in solvent and dry it thoroughly with compressed air. Do not use sandpaper or other abrasive to clean the atomizer head because alteration of the fuel spray pattern may result.

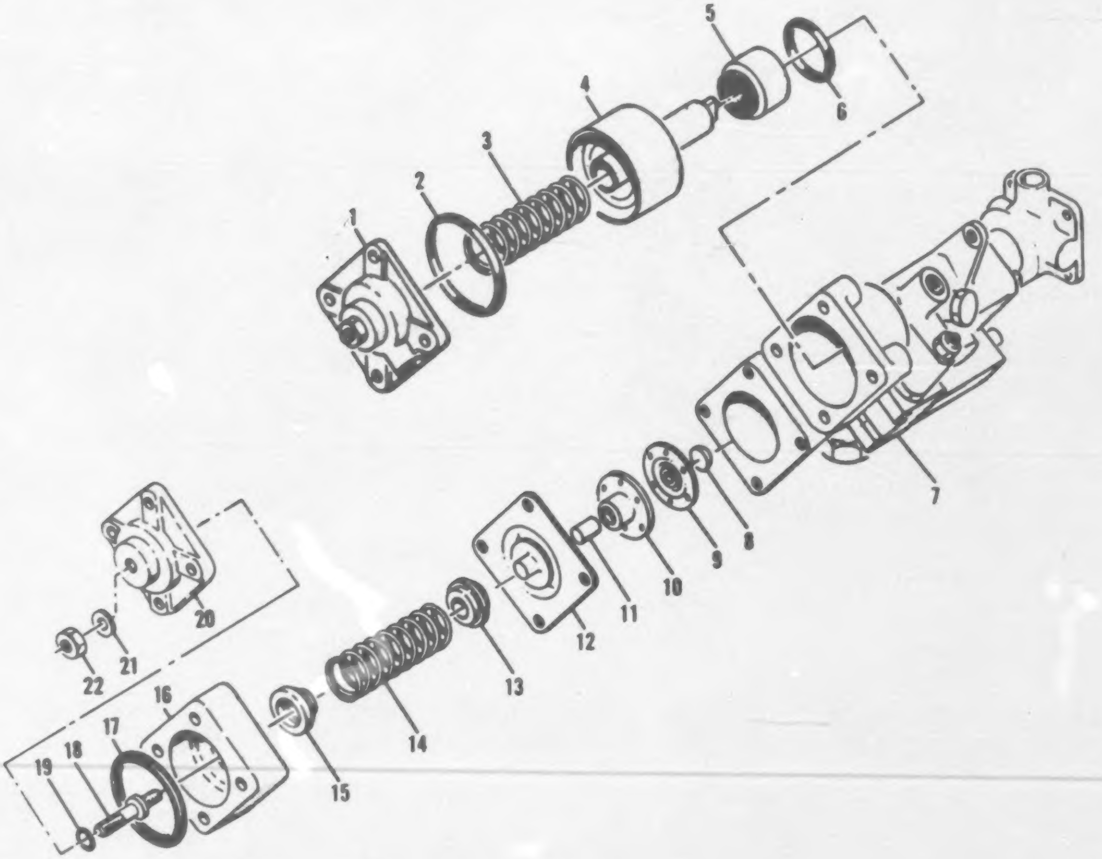
The seal for the fuel pump and control unit governor (fig. 12-16 can be replaced by removing the screws and washers attaching the cover assembly, cover assembly packing, and spring. A puller must be used to remove the governor cage with governor sleeve and shaft assembled and the carbon seal. The packing can now be removed and replaced. Press a new carbon seal in place avoiding contact with the carbon ring face when pressing in place. Reinstall the governor cage with assembled sleeve and shaft in housing, and install the spring, new packing, and the governor cover assembly. To adjust the fuel pump and control unit governor, first loosen the nut on the adjusting screw located on the governor cover assembly. Next turn the adjusting screw clockwise to increase governor speed or counterclockwise to reduce governor speed and tighten the nut.

To replace the acceleration limiter valve diaphragms, remove screws and nuts attaching the cover assembly and remove the cover assembly. Next remove the packing, spacer, nut, spring, spring seat, diaphragm assembly, and pin and separate the retainer from the diaphragm. Reassemble the acceleration limiter valve in reverse order of disassembly using new diaphragms and packing. To adjust the acceleration limiter valve, begin by disconnecting the fuel line at the atomizer assembly and attach the fuel line to a suitable fuel pressure gage of 0 to 100 psi range with 1.00



1. Generator.
2. Seal.
3. Carrier assembly–main drive gear bearing.
4. Packing–generator adapter.
5. Shim–generator adapter.
6. Shim–generator adapter.
7. Housing–accessory.
8. Motor–starter.
9. Switch–centrifugal.
10. Cover–tachometer-generator pad.
11. Gasket.
12. Retainer.
13. Seal–oil pump shaft.
14. Packing.
15. Case–oil filter.
16. Element–oil filter.
17. Packing–O-ring.
18. Packing–O-ring.
19. Pump assembly–oil.
20. Valve–oil drain solenoid.
21. Cap–fuel filter.
22. Spring–fuel pump filter.
23. Element–fuel pump filter.
24. Packing–O-ring.
25. Packing–O-ring.
26. Pump and control unit–fuel.
27. Seal–accessory assembly oil pump shaft.
28. Retainer.
29. Gasket.
30. Insulator.
31. Gasket.
32. Bracket–mounting.

Figure 12-15.–Accessory section. 227.74



1. Cover assembly—governor.
2. Packing.
3. Spring.
4. Cage—governor.
5. Seat.
6. Packing.
7. Pump and control unit—fuel.
8. Valve—acceleration limiter.
9. Diaphragm—acceleration limiter valve.
10. Retainer—acceleration limiter value diagram.
11. Pin.
12. Diaphragm—fuel pump and control unit.
13. Seat—spring.
14. Spring.
15. Retainer—spring.
16. Spacer—cover.
17. Packing.
18. Screw—adjusting.
19. Packing—O-ring.
20. Cover.
21. Washer.
22. Nut.

227.75

Figure 12-16.—Fuel pump and control unit.

psi increments. Now disconnect the pneumatic control line from the acceleration control port on the fuel pump and control unit. Press the start switch and wait until the motor unit speed levels off and note the fuel pressure indication on the pressure gage. The fuel pressure must be between 46.0 and 48.0 psig. After loosening the nut on the adjusting screw, turn the screw clockwise to increase fuel pressure and counterclockwise to decrease fuel pressure as necessary to meet prescribed limits. To complete the adjustment, tighten the adjusting nut, remove the fuel pressure gage, connect the pneumatic control line to the fuel pump and control unit, and connect the fuel line to the atomizer assembly.

To replace the oil filter element (16, fig. 12-15) remove the filter case from the oil pump assembly and after removing the filter element, wash the case with solvent and blow dry with filtered compressed air. Before a new cylindrical filter element is installed inspect the case carefully for any damage or imperfections. Also inspect the packings and replace if necessary.

The replacement of the accessory assembly oil pump shaft seal (27, fig. 12-15) can be accomplished by removing the fuel pump and fuel control unit. This is necessary in order to gain access to the oil pump. Now remove the oil pump assembly and take out the seal and retainer. The mechanical seal puller should be used to preclude damage to the shaft. Install the new seal with the installing tool and reinstall the oil pump assembly and the fuel pump and control unit.

The procedure for adjustment of the acceleration stabilizer and adjustable orifice assembly requires that the cap be removed from the tee located adjacent to the acceleration stabilizer and adjustable orifice assembly solenoid valve and install a flex-line with a calibrated 0 to 30 psi pressure gage. Next, start the unit normally and run at no-load governed speed for at least 1 minute to allow temperatures and pressures to stabilize. To determine the correct no-load control pressure for the current ambient temperature, use the chart in figure 12-17. If the indicated gage pressure is not within the maximum-minimum band on the chart, adjust the screw in the adjustable orifice assembly adjacent to the acceleration limiter solenoid valve in a clockwise direction to increase the control air pressure or in a counterclockwise direction to decrease the pressure. Next, shut down the unit, remove the flex-line with gage, and reinstall the cap on the tee.

After the adjustment of the acceleration stabilizer and adjustable orifice assembly, the unit needs checking. If the unit fails to accelerate to 30-percent rated speed after start, shut it down immediately. Disconnect the electrical connector at the oil pressure switch assembly, start the unit, and check all control air tubing assemblies and fittings for leaks. While the unit is running, place your finger over the two bleed holes in the adjustable orifice assembly. Leakage through these holes indicates a defective acceleration limiter solenoid which should be replaced and rechecked. The duty cycle of the starter is 1 minute on and 4 minutes off. When the unit makes a satisfactory start and will accelerate to 30 percent rated speed, but will not exceed that speed, check all control air tubing assemblies and fittings for leakage and foreign material. Repair leaks or replace tubing and clean away any unnecessary material. When adjustment requirements and checks are complied with and the unit still fails to start, the starting difficulty must be attributed to other causes. Consult the Maintenance Instructions Manual for further information.

To adjust the starter motor clutch, remove starter motor assembly (8, fig. 12-15). To prevent any rotation of the starter armature, install the starter motor assembly in a suitable holder (fig. 12-18). Using an adapter for the torque wrench, check the slip torque. Slip torque must be between 100 and 110 inch-pounds. If the slip torque is not within these limits, remove the retainer and all parts but the washers. Add or remove washers to obtain the desired torque. Last, reassemble the starter motor and reinstall on the accessory housing.

For testing the gas turbine compressor to make sure that the unit adheres to a given set of

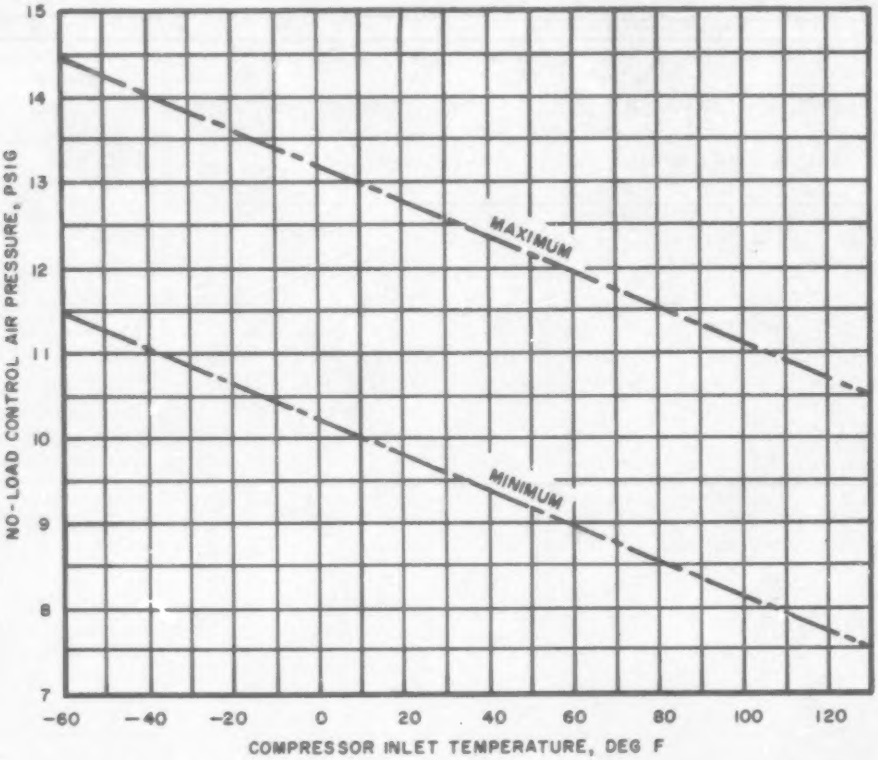


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Figure 12-17.—Temperature curve for setting acceleration stabilizer and adjustable orifice assembly.

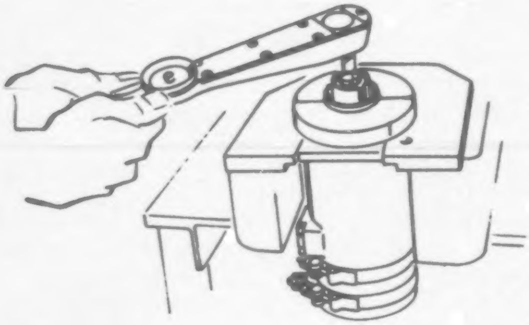

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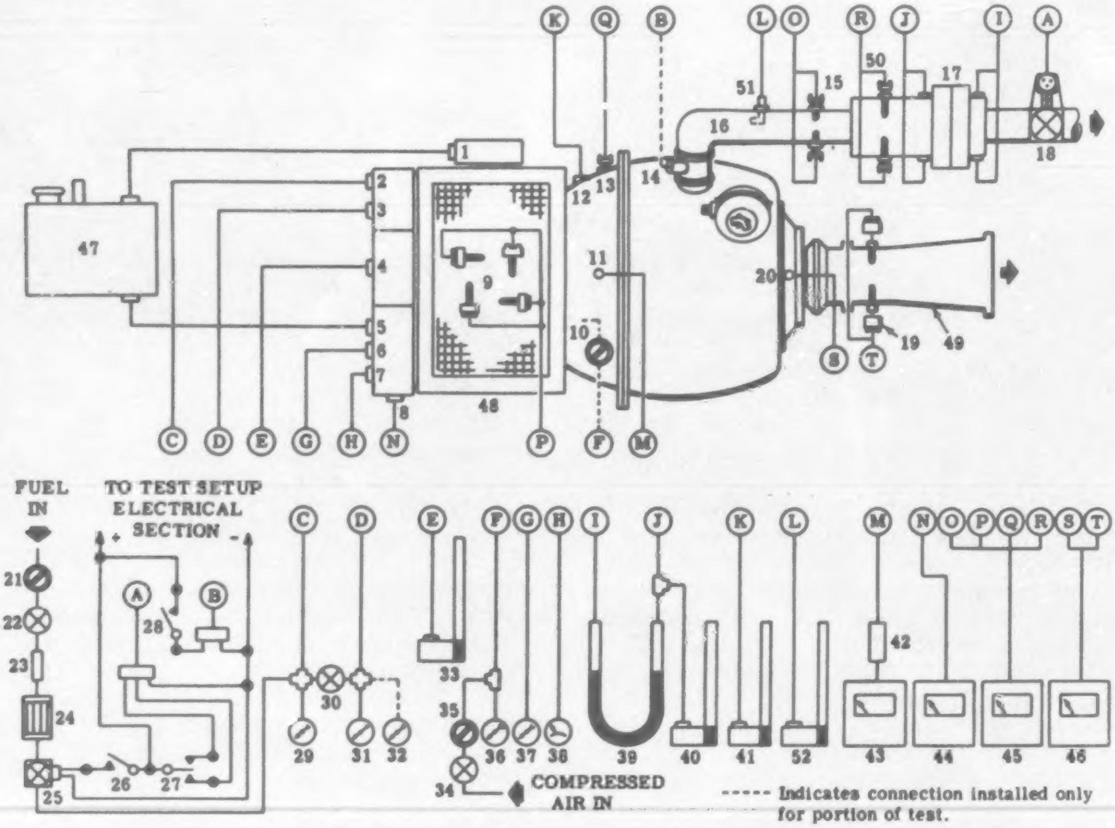
Figure 12-18.—Checking clutch slip torque.

operational and functional requirements when subjected to a specified set of operating conditions, a test stand is used. The test stand incorporates test setups such as shown in figure 12-19. The test stand should be designed so that all sides, top, and bottom of the unit are readily accessible and so arranged that exhaust gases do not enter the compressor air inlet. Vibration isolation mounting should be provided between the unit and points of attachment. Complete, accurate records should be kept of all test information, and a separate set of records should be used for each unit and kept as a permanent record of the unit. The required values for each test, if not specified, must be individually determined as outlined in the instructions and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COMPRESSED AIR IN

----- Indicates connection installed only for portion of test.

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Figure 12-19.—Fuel, oil, and pneumatic section test setup.

entered on the record sheets. The test stand is also used for run-in after overhaul.

NOTE: The following references will assist the ASM in performing maintenance on gas turbine engines.

1. NAVAIR 19-105B-12, Pneumatic Power Gas Turbine Engine, Model No. GTC85-72.
2. NAVAIR 19-105B-30, Pneumatic and Shaft Power Gas Turbine Engine, GTCP100-54.
3. NAVAIR 19-105B-36, Compressor Power Units NCPP-105.
4. NAVWEPS 19-105BC-1, Gas Turbine Engine Analyzer.
5. NAVAIR 07-1-503, Cleaning Materials for Naval Weapons Systems Maintenance and Overhaul Operations.

CHAPTER 13

AIR CONDITIONERS

Mobile air conditioners are primarily designed to remove the heat produced by operating electronic equipment and to reduce the humidity within electronic equipment spaces while the aircraft is undergoing maintenance, thereby limiting the ambient (surrounding) temperature and humidity within the aircraft to the level specified for the equipment.

Air conditioning encompasses more than the transfer of heat from one place to another. Although it is usually thought of as a lowering of temperature, air can be conditioned by cooling, heating, filtering, or dehumidifying. Modern mobile air conditioners are designed to accomplish all of these to condition air for electronic equipment spaces within naval aircraft.

Mobile air conditioners are referred to as mechanical refrigeration systems because mechanical means are used to circulate a refrigerant through a closed system to accomplish heat transfer.

Basically, the purpose of all refrigeration systems is heat transfer. To understand the basic principles of refrigeration, a definite understanding of the relationship of heat, temperature, and pressure is mandatory.

The NR-5C and NR-10 air conditioners are used in this chapter as the typical equipment used ashore and afloat.

TERMINOLOGY

In the study of refrigeration and air conditioning, it is essential that the meaning of certain terms, as they are applied to refrigeration and air conditioning, be understood. The terms listed and defined here apply to any refrigeration or air-conditioning system of the mechanical type.

1. BRITISH THERMAL UNIT (Btu). The amount of heat required to produce a temperature change of 1° F in 1 pound of water at sea level pressure.
2. CHANGE OF STATE. The change of any matter from one state (solid, liquid, or vapor) to another.
3. COMPRESSION. The act of increasing the pressure and temperature of a substance by decreasing its volume.
4. CONDENSATION. The process by which a vapor changes state to a liquid when heat is removed from the vapor, or when pressure is increased on the vapor.
5. CONDUCTION. Heat transfer from molecule to molecule within a substance or between two substances that are in physical contact with each other.
6. CONVECTION. Heat transfer through some easily circulated medium (usually liquid or vapor). As the medium moves, it carries with it its contained heat energy, which is then tranferred to the surroundings.
7. CYCLE. The complete course of operation of a refrigerant, from starting point back to starting point, in a closed refrigeration system.
8. DEHUMIDIFY. To reduce the quantity of water vapor in a given space.
9. EVAPORATION. The process by which a liquid changes state to a vapor when heat is added to the liquid, or when pressure is decreased on the liquid.

10. HEAT. A basic form of energy which is transferred by virtue of a temperature difference. Heat always flows from a hot object to a cold object, and the greater the temperature difference, the faster the flow. Heat cannot be manufactured or destroyed–only transferred.

11. HEAT OF CONDENSATION. The latent heat given up by a substance as it changes state from a vapor to a liquid.

12. HEAT OF FUSION. The latent heat absorbed as a substance changes state from a solid to a liquid.

13. HEAT OF VAPORIZATION. The latent heat absorbed by a substance as it changes state from a liquid to a vapor.

14. LATENT HEAT. Heat applied to, or removed from, a substance which causes a change in the physical state of the substance, but not in its temperature.

15. LOAD. The amount of heat imposed upon a refrigeration system in a specified amount of time, or the required rate of heat transfer, expressed in Btu per hour.

16. PRESSURE. Force per unit area, measured in pounds per square inch; pressure is directly proportional to temperature.

17. REFRIGERATION TON. The transfer of heat at a rate of 288,000 Btu in 24 hours (12,000 Btu in 1 hour).

18. SENSIBLE HEAT. Heat applied to, or removed from, a substance which causes a change in the temperature of the substance, but not in its state.

19. SUPERHEAT. Heat added to a vapor above the boiling point of the liquid which produced the vapor. The vapor and the liquid must be separated before the vapor can be superheated.

20. TEMPERATURE. A measure of the heat intensity or concentration of heat (thermal energy) in a body or substance, measured in degrees.

21. VACUUM. Any pressure less than atmospheric pressure.

22. VAPOR. Gaseous form of any substance. Vapor condenses very readily to a liquid state under small changes of temperature or pressure, or both. It may be said to be very close to the liquid state, although it is a vapor.

REFRIGERANTS

A refrigerant is a substance that can easily be changed from a liquid state to a vapor state. Ideally, it is a substance having a low boiling point and the capability to absorb and carry heat at a low temperature and to transfer this heat to a cooling medium, either air or water, as it condenses.

Most refrigerants in use today require comparatively low pressures in the system; thus, equipment does not require heavy construction, and leaking tendencies are reduced to a minimum.

In order to prevent confusion and to provide for standardization among users, all refrigerants are assigned numbers rather than trade names, and are referred to as refrigerant 12, refrigerant 22, etc.

The two most commonly used by the Navy, refrigerant 12 and refrigerant 22, are discussed in this manual.

REFRIGERANT 12

Research for the perfect refrigerant resulted in R-12; it approaches that ideal more than any other so far discovered. Its chemical name and symbol, dichlorodifluromethane (CCl_2F_2), indicate that R-12 contains one part carbon, two parts chlorine, and two parts fluorine.

At atmospheric pressure, R-12 boils at +21.7°F. and its latent heat of vaporization at atmospheric pressure is about 72 Btu per pound; that is, as R-12 changes state to a vapor at atmospheric pressure, it absorbs 72 Btu per pound.

Some of the advantages of R-12 are:

1. It is nonflammable, nonexplosive, and noncorrosive.
2. Its vapor is nontoxic.
3. At the low-pressure point of its cycle, it operates at pressures slightly above atmospheric pressure, thus minimizing the possiblity of air entering the system.
4. At the high-pressure point of its cycle, pressure is comparatively low, allowing the use of lightweight equipment.

REFRIGERANT 22

R-22, like R-12, is a member of the fluorinated hydrocarbon family. Its chemical name and symbol, monochlorodifluoromethane ($CHClF_2$), indicate that R-22 contains one part carbon, one part hydrogen, one part chlorine, and two parts fluorine.

At atmospheric pressure R-22 boils at -41° F, and its latent heat of vaporization is about 92 Btu per pound. This capability to absorb great amounts of heat, combined with its low boiling point, mades R-22 a very good refrigerant for use in systems of high capacity and very low temperatures, such as refrigerators, freezers, and modern compact air conditioners.

R-22 requires higher pressures in its cycle than R-12 and, consequently, slightly heavier construction of system components, With this exception, all of the advantages associated with R-12 also apply to R-22.

One inherent disadvantage which is shared by both of these refrigerants is the capacity to absorb water, making the use of chemical driers mandatory to prevent freezeups of the expansion valves.

REFRIGERATION CYCLE

The refrigeration cycle is divided into two pressure sections, the high-pressure side and the low-pressure side. The dividing lines between these two pressure areas are the compressor and the thermal-expansion valve, as shown in figure 13-1.

As the refrigerant flows through the system, it assumes four different and distinct states.

1. Low-pressure vapor.
2. High-pressure vapor.
3. High-pressure liquid.
4. Low-pressure liquid.

As shown in figure 13-1, the high side starts as the pistons in the compressor compress the vapor and force it out through the compressor discharge valves. As the pressure of the vapor is increased, its temperature is also increased, thereby becoming superheated vapor.

When the hot, high-pressure vapor leaves the compressor, it flows directly to the condenser coil.

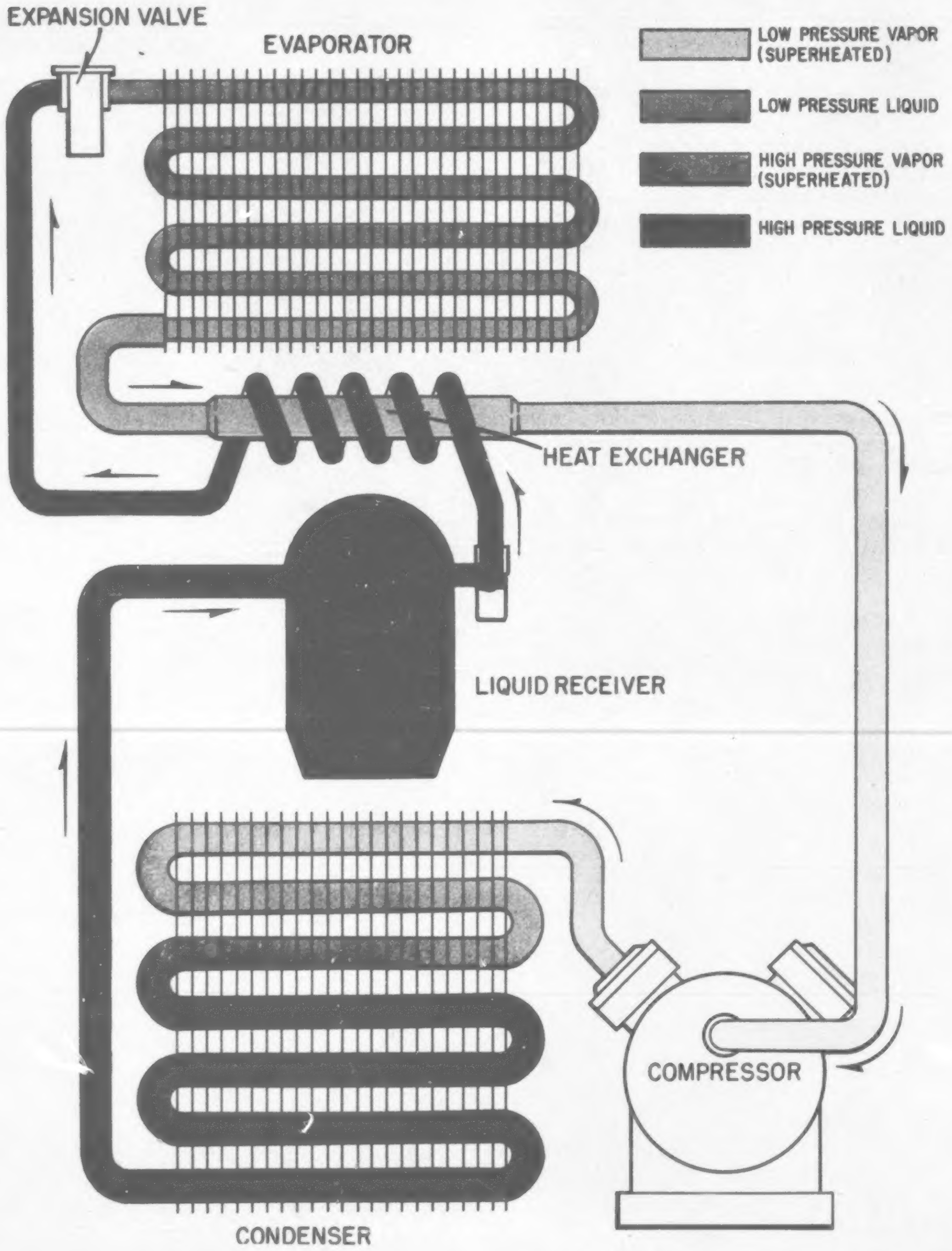
The hot vapors from the compressor enter the condenser at the top. Cooling air is circulated over the condenser coil by the condenser fan. As the refrigerant cools, giving up the latent heat of condensation to the condenser tubes where it is transferred to the cooling air by conduction, it changes state into a liquid and drains through an outlet fitting in the bottom of the condenser. As the liquid passes through the bottom set of tubes, its temperature is lowered below the condensing temperature. This is known as subcooling. Subcooling of the refrigerant increases the capacity of the unit by allowing the refrigerant to absorb a greater amount of heat before reaching the point of vaporization.

From the condenser coil, the high-pressure liquid refrigerant flows to the liquid receiver, which acts as a reservoir for the liquid refrigerant, and forms a liquid seal on the liquid line to prevent backflow when the unit is shut down.

After leaving the receiver, the high-pressure liquid refrigerant flows to the thermal expansion valve. As the refrigerant is metered and passes through the thermal expansion valve, it undergoes a change in pressure, becoming a low-pressure liquid. This is the beginning of the low-pressure side of the system. As pressure on the refrigerant is decreased, its boiling point is correspondingly decreased.

The low-pressure liquid then enters the evaporator coil. At the evaporator coil, heat is transferred by conduction from the air to be conditioned to the coils of the evaporator and then to the liquid refrigerant within the evaporator, thus beginning a change of state of the liquid refrigerant into a vapor. The heat absorbed by the refrigerant within the evaporator is known as the latent heat of vaporization. The refrigerant is now a mixture of liquid and vapor and continues through the evaporator, absorbing more heat and changing all the liquid to vapor. The change of state is now complete and the vapor will be superheated as it passes on through the evaporator.

After leaving the evaporator, the low-temperature, low-pressure vapor is returned


EXPANSION VALVE
EVAPORATOR
LOW PRESSURE VAPOR (SUPERHEATED)
LOW PRESSURE LIQUID
HIGH PRESSURE VAPOR (SUPERHEATED)
HIGH PRESSURE LIQUID
HEAT EXCHANGER
LIQUID RECEIVER
COMPRESSOR
CONDENSER

225.178

Figure 13-1.—Fundamental refrigeration cycle.

to the suction side of the compressor, completing the cycle.

This cycle is repeated as long as the compressor is operating. As can be seen from the description just given, the basic refrigeration or air-conditioning cycle is compression, condensation, expansion, and evaporation. The flow in a basic system is from the compressor, through the condenser coil, to the receiver, through the expansion valve, through the evaporator coil, and back to the compressor.

MAJOR COMPONENTS

Compressor

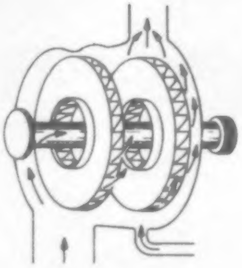
Compressors used in refrigeration and air-conditioning units have but one purpose–to withdraw the heat-laden refrigerant vapor from the evaporator and compress the vapor to such an extent that it will, by cooling only a few degrees, liquify in the condenser. The design of the compressor depends upon the application and type of refrigerant used in the system. There are three types of compressors, classified according to their principle of operation–reciprocating, rotary, and centrifugal. (See fig. 13-2.)

The function of the compressor is the same for all three types, but the mechanical means used to accomplish this function differ considerably. The only type discussed in this manual is the reciprocating, since this is the type used on the mobile air conditioners the ASM is required to troubleshoot and maintain.

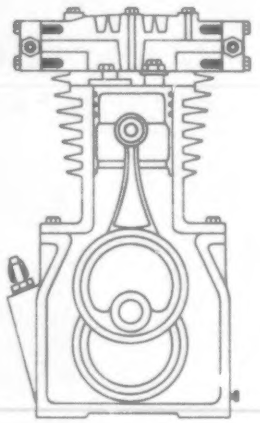
Reciprocating compressors used in air conditioning and refrigeration are designated as either open, semihermetic, or hermetic.

The open type of compressor (fig. 13-3) is driven from an external power source through "V" belts, gears, or a flexible coupling, and is used on mobile air conditioners which are powered by a gasoline or diesel engine.

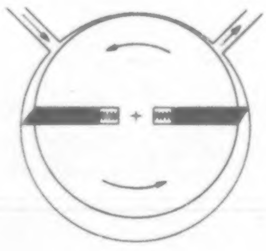
The semihermetic type of compressor (fig. 13-4) is a motor-compressor combination enclosed within a common housing. It is provided with access plates and can be serviced in the field if necessary. It is capable of



CENTRIFUGAL



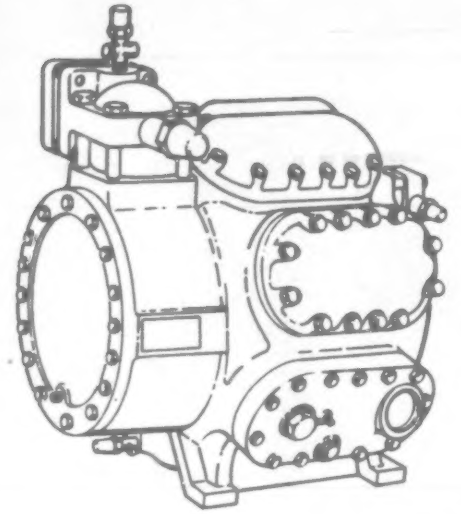
RECIPROCATING



ROTARY

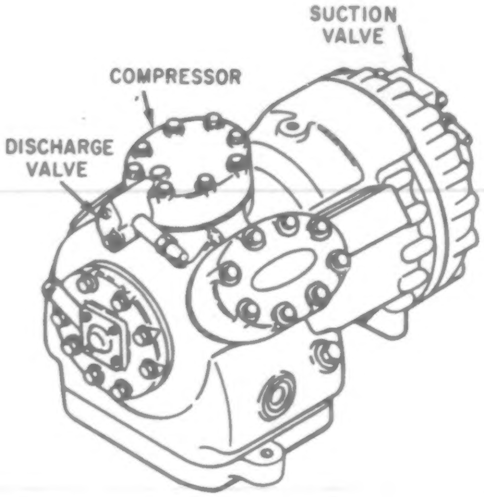
225.179

Figure 13-2.—Compressor types.



225.180

Figure 13-3.—Reciprocating open compressor.



225.181

Figure 13-4.—Reciprocating semihermetic compressor.

maintaining a larger volume of refrigerant flow than an open type of the same size because it and its electric driving motor operate on a common shaft and at the same speed. This type of compressor, in multicylinder versions (4 or 6), is used on mobile air conditioners that are electrically powered.

The hermetic type of compressor (fig. 13-5) is a motor-compressor combination encased within a gastight, welded casing that cannot be opened for servicing except in refrigeration component overhaul shops. This type is used on refrigerators, freezers, window air conditioners, or any small unit.

The operation of all reciprocating compressors is basically the same. The piston is actuated by a connecting rod attached to a crankshaft which is turned by the driving force. As the piston moves down toward its lowest position, a low-pressure area is formed within the cylinder. As indicated in figure 13-6 (A), the suction (intake) valve opens when the pressure within the cylinder becomes less than the pressure in the suction line leading to the cylinder. When the intake valve opens, the cylinder is filled with low-pressure refrigerant vapor.

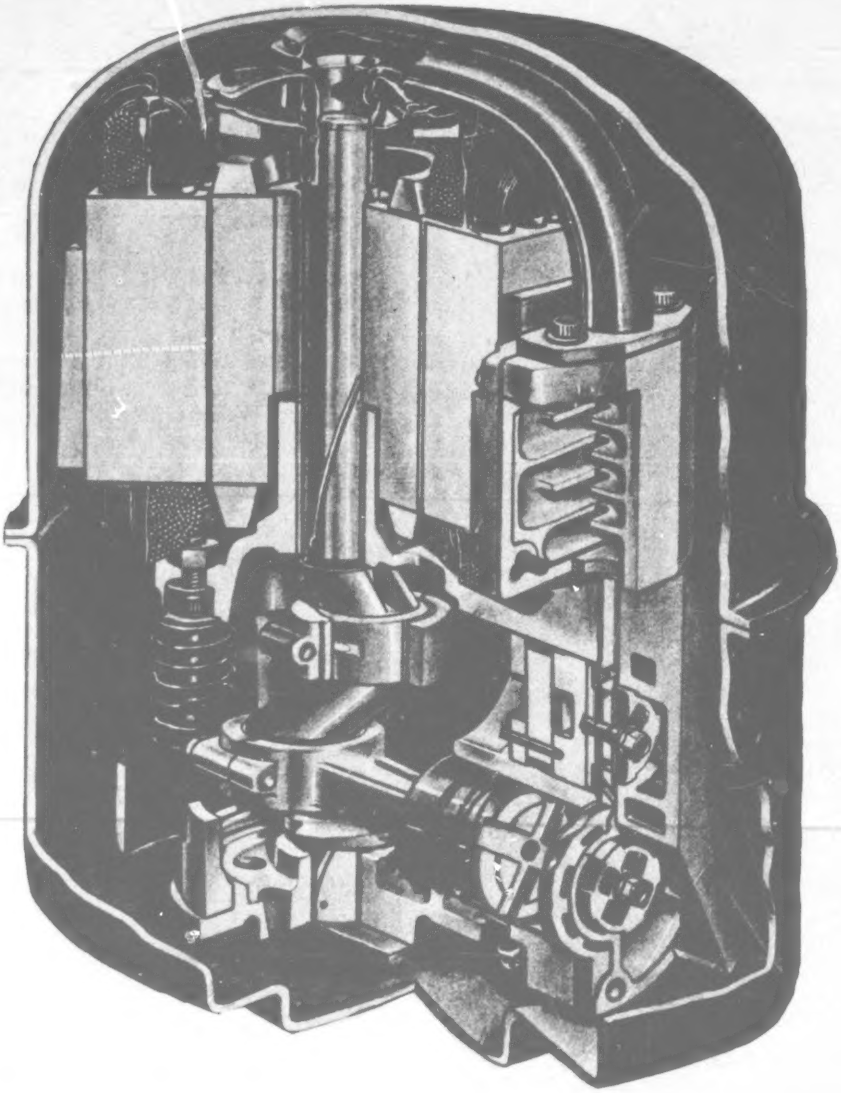
As the piston moves upward, (fig. 13-6 (B)), the intake valve closes when the pressure within the cylinder becomes greater than the pressure in the suction line. As the piston continues its upward travel, the discharge valve opens when pressure within the cylinder becomes greater than the pressure in the discharge line, and the compressed refrigerant vapor is discharged to the high-pressure side of the system.

Reciprocating compressors are lubricated either by pressure from an oil pump or by splash as the crankshaft turns in the oil in the crankcase of the compressor.

Condenser

The purpose of the condenser in a refrigeration system (fig. 13-1) is to convert the hot refrigerant vapor from the compressor into a liquid state, making it ready for use again in the evaporator. The condenser accomplishes this by removing heat from the hot vapor, causing it to condense at the pressure existing in the high-pressure side of the system.

There are two general types of condensers, the air cooled and the water-cooled.



225.182

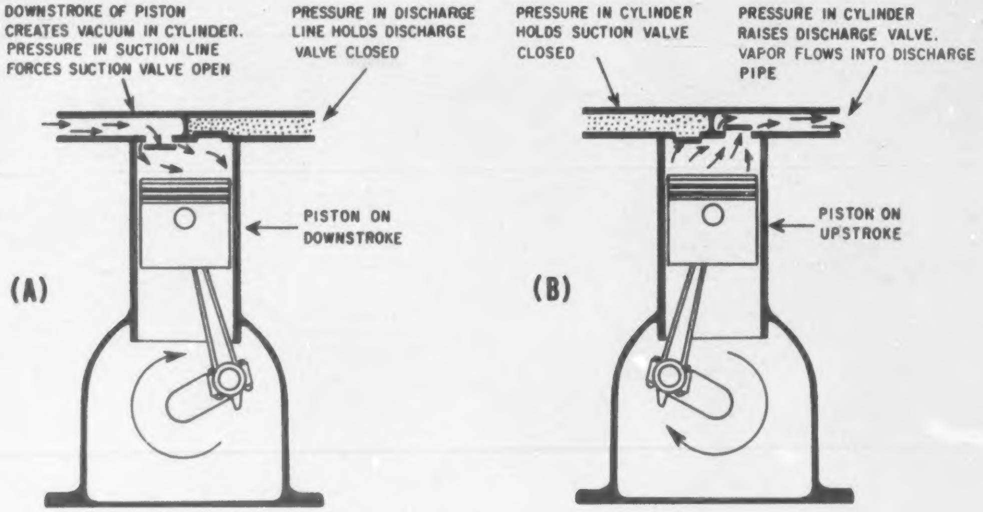
Figure 13-5.—Reciprocating hermetic compressor.

The air-cooled condenser (fig. 13-7) utilizes a flow of ambient (surrounding) air through the coils of the condenser to provide a cooling effect. Maximum condenser surface is obtained by closely spaced fins on the coils. The coil and fin arrangement is similar to that of an automobile radiator.

Maintenance of air-cooled condensers used on mobile air conditioners is relatively minor, consisting of keeping the coil and fins free of dust and dirt. This should be done with care so as not to bend or damage the coil and fins.

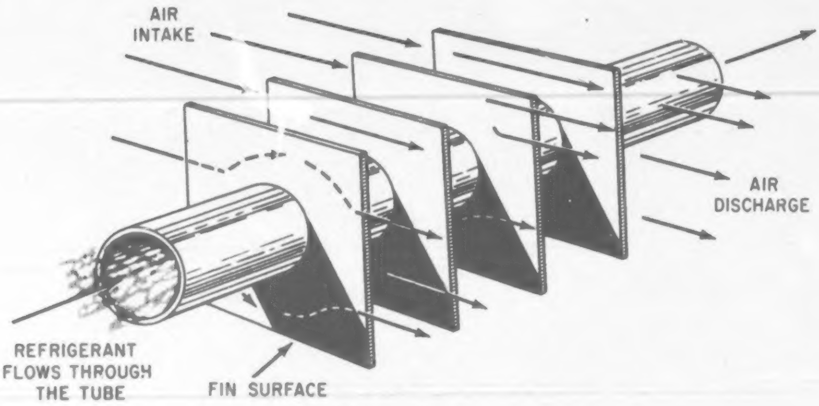
Receiver

The receiver (fig. 13-1) is installed to collect the liquid refrigerant as it leaves the condenser. It serves as a reservoir for the refrigerant and


DOWNSTROKE OF PISTON CREATES VACUUM IN CYLINDER. PRESSURE IN SUCTION LINE FORCES SUCTION VALVE OPEN
PRESSURE IN DISCHARGE LINE HOLDS DISCHARGE VALVE CLOSED
PISTON ON DOWNSTROKE
(A)
PRESSURE IN CYLINDER HOLDS SUCTION VALVE CLOSED
PRESSURE IN CYLINDER RAISES DISCHARGE VALVE. VAPOR FLOWS INTO DISCHARGE PIPE
PISTON ON UPSTROKE
(B)

225.183

Figure 13-6.—Operating cycle of a reciprocating compressor.

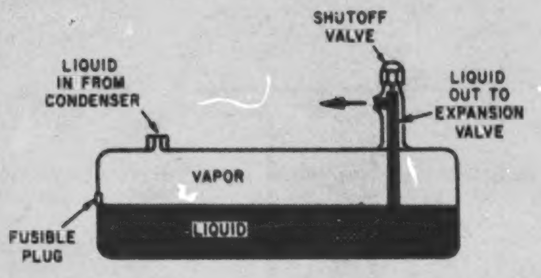

AIR INTAKE
AIR DISCHARGE
REFRIGERANT FLOWS THROUGH THE TUBE
FIN SURFACE

225.184

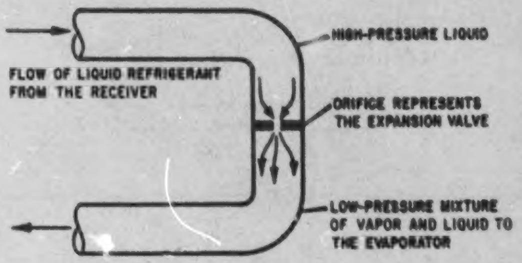
Figure 13-7.—Construction detail of air-cooled condenser.

maintains a liquid seal on the liquid line to the expansion valve.

Receivers (fig. 13-8) are designed to be large enough to hold the complete charge of refrigerant required for the unit to operate. They are equipped with shutoff valves on the inlet and outlet lines to permit maintenance personnel to pump the unit down (entrap all refrigerant in the receiver) when work is being done on another component of the system. With



225.185
Figure 13-8.—Refrigerant receiver.


HIGH-PRESSURE LIQUID
FLOW OF LIQUID REFRIGERANT FROM THE RECEIVER
ORIFICE REPRESENTS THE EXPANSION VALVE
LOW-PRESSURE MIXTURE OF VAPOR AND LIQUID TO THE EVAPORATOR

225.186
Figure 13-9.—Expansion valve principle.

the shutoff valves closed, no loss of refrigerant occurs.

Some receivers are equipped with liquid sight glasses to show the liquid level during operation. The receiver is normally about 1/3 full during operation.

Expansion Valve

The function of the expansion valve (fig. 13-1), also referred to as a metering device, is to change the high-pressure liquid into a low-pressure saturated vapor as it enters the evaporator, and to regulate the flow of liquid refrigerant into the evaporator to ensure the correct quantity of refrigerant flow to keep the evaporator operating at maximum efficiency without overloading the compressor. The action of the valve is similar to a spray nozzle in that the liquid refrigerant enters the evaporator as a mist or spray.

Many different types of metering devices are in use in air-conditioning systems today. The basic types are automatic expansion valves, thermostatic expansion valves, and capillary tubes. Regardless of the complexity of design of any particular device, the principle involved is the same as that shown in figure 13-9. When a gas or liquid is forced through a small opening, the pressure decreases and the gas or liquid expands.

The thermostatic valve is the type of expansion valve used on mobile air conditioners, so it is the one discussed in this manual.

The thermostatic expansion valve (fig. 13-10) consists essentially of a diaphragm connected by a small tube to a temperature-sensitive bulb attached to the refrigerant tubing at the discharge side of the evaporator. The bulb is filled with the same refrigerant as that used in the system. Connected to the diaphragm, inside the valve housing, are the valve and spring.

The thermostatic expansion valve ensures that the amount of refrigerant which enters the evaporator is in proportion to the rate of evaporation of the refrigerant. Thus, the expansion valve regulates refrigerant flow in proportion to refrigerant evaporation. The rate of evaporation of the spray or mist is dependent upon the rate of heat absorption from the air passing through the evaporator. The liquid refrigerant enters the evaporator in the form of a low-pressure mist or spray. Because heat is absorbed by the mist as it travels through the evaporator, the mist changes to a vapor and, when all the liquid is changed to a vapor, any additional heat that is absorbed by the vapor is called superheat. By the time the refrigerant leaves the evaporator, all of it should be in the superheated vapor form.

In figure 13-11 a thermostatic expansion valve is shown with the evaporator for a typical cooling unit operating at 37-psi suction (low-side) pressure. The refrigerant moving through the coil absorbs heat from the air outside the coil until, at point B, it has absorbed sufficient latent heat for a complete vaporization. At this point, all the liquid has

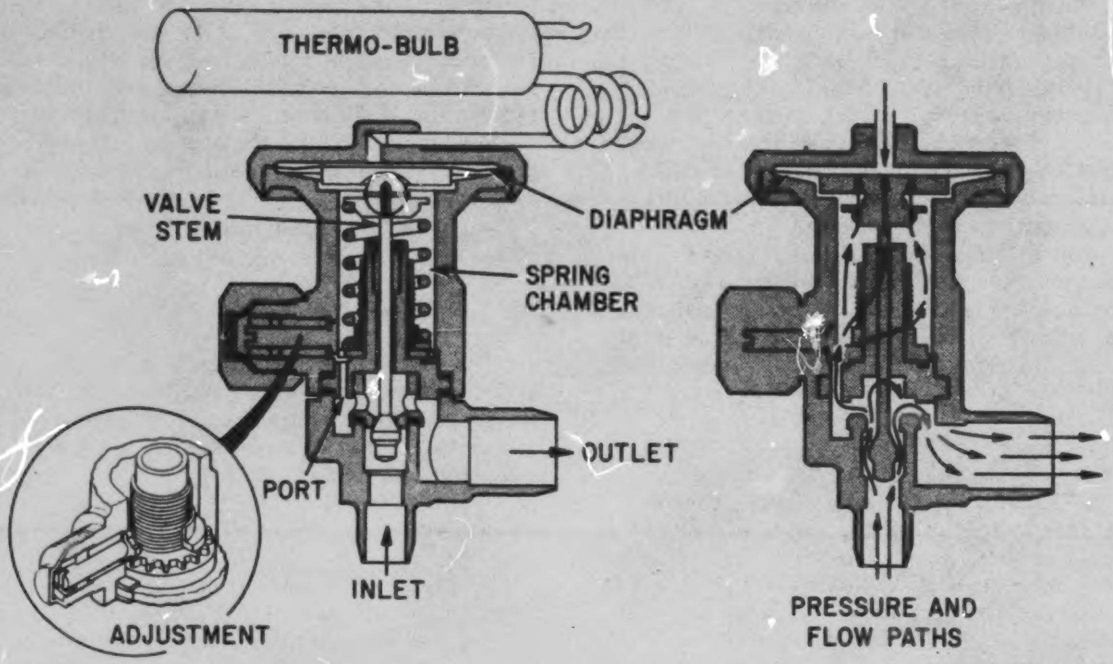
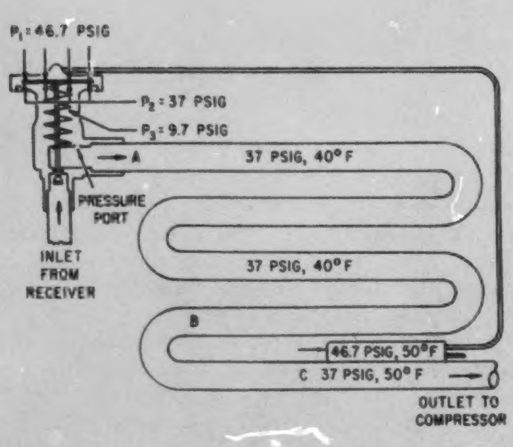

THERMO-BULB
VALVE STEM
DIAPHRAGM
SPRING CHAMBER
OUTLET
PORT
INLET
ADJUSTMENT
PRESSURE AND FLOW PATHS

Figure 13-10.–Thermostatic expansion valve. 225.187


P_1 = 46.7 PSIG
P_2 = 37 PSIG
P_3 = 9.7 PSIG
A
37 PSIG, 40° F
PRESSURE PORT
INLET FROM RECEIVER
37 PSIG, 40° F
B
46.7 PSIG, 50° F
C 37 PSIG, 50° F
OUTLET TO COMPRESSOR

225.188
Figure 13-11.–Superheat action in an evaporator.

vaporized. Any additional heat now absorbed from the air raises the temperature of the vapor, but the pressure remains at 37 psi because this is the suction pressure of the compressor. By the time the vapor reaches the thermal bulb, point C, it has been superheated according to the thermal expansion valve setting; in the figure, an additional 10° F has been absorbed.

SUPERHEAT REGULATION.–The temperature of the refrigerant within the thermal bulb is 50° F, the same as the temperature of the suction vapor at this point. The pressure within the thermal bulb, and consequently on the diaphragm within the thermal expansion valve, is 46.7 psi (PI). This pressure tends to push the diaphragm down, opening the valve from the receiver. Opposing this force is the 37 psi (P2) exerted against the bottom of the diaphragm by the vapor at the inlet of the evaporator coil. A spring pressure of

9.7 psi (P3) added to 37 psi (P2) holds the valve in equilibrium at 10° F superheat.

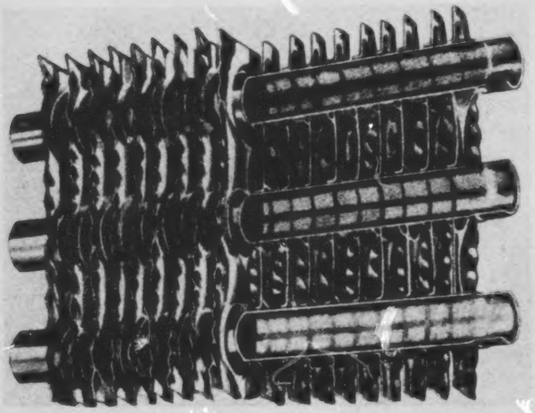
If an increase in load occurs, the superheat in the suction vapor increases, causing the thermal bulb temperature and pressure to increase, exerting a greater pressure on the top of the diaphragm. This causes the valve to open further, allowing an increase in the flow of refrigerant to the evaporator to restore the superheat to the 10° setting of the valve.

If a decrease in load occurs, the superheat decreases and the pressure in the thermal bulb decreases. Evaporator inlet pressure plus spring pressure tend to close the valve, reducing the flow of refrigerant sufficiently to maintain the superheat at 10°.

Evaporator

The evaporator (fig. 13-12) is a bank or coil of thin-walled tubing mounted in a block of thin metallic fins. It is here that the refrigerant absorbs heat. The evaporator coil is cooled by the refrigerant absorbing heat from the tubing; then the air to be cooled is directed over the cold coil, and cooling of the air is accomplished.

HEAT REMOVAL.—As the warm air is passed over the outside of the evaporator coils, heat is transferred from the air to the refrigerant through the fins and metal walls of the coil. Heat is transmitted from the warm air to the fin surfaces, to the circular pipe, and then to the refrigerant. The heat applied to the outside of the tube causes the refrigerant to boil. As a result of boiling, the liquid changes into a vapor, but remains at the same low pressure. This vapor is then drawn back to the suction side of the compressor. Also, as the warm humid air comes into contact with the cold coil, moisture in the air is condensed and drips down off the evaporator.



225.189

Figure 13-12.—Construction detail of an evaporator.

ACCESSORY COMPONENTS

There are various accessories that can be added to the major components to provide either simplified maintenance or increased efficiency without changing the function of the refrigeration system.

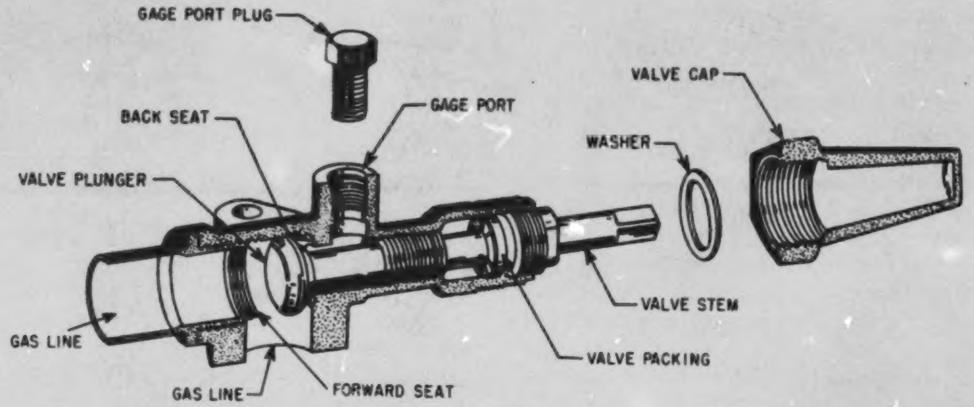
Service Valves

Service valves, referred to as head and suction valves, are provided for charging the system and for use during some maintenance operations. The head valve is mounted on the high-pressure port of the compressor, and the suction valve is mounted on the low-pressure side. Construction of the valves and their method of operation are identical. (See fig. 13-13.) However, they differ in size, use, and placement.

The valve cap for the compressor service valve is designed to be used as a dust cover and to protect the service valve. The valve cap and gasket must be removed to position the valve plunger. The valve plunger can be positioned in the forward seated, back seated, or cracked position. Always use the wrenches provided with the air conditioner for adjusting the service valves.

To forward seat a service valve (fig. 13-13), turn the valve stem clockwise as far as it will go. This puts the plunger to the left and tight against the forward seat and stops gas flow at this point.

To back seat a service valve, turn the valve stem counterclockwise as far as it will go. The valve plunger is now to the right and tight against the back seat. The gas line is now completely open.



225.190

Figure 13-13.—Service valve.

To crack a service valve, first back seat and then turn the valve stem one-forth turn clockwise. This moves the valve plunger slightly to the left, and allows gas to flow into the gage port.

To install a pressure gage in a service valve, back seat and remove the gage port plug; then insert the gage and crack the service valve so the gage will read.

Never operate the compressor with the head service valve forward seated. This condition blocks the output of the compressor and causes the pressure of the compressor to build up sufficiently to become dangerous to personnel. Also, the compressor will almost certainly suffer damage.

Vibration Eliminators

Vibration eliminators absorb and remove inherent vibration in copper tubing caused by floating components. They are constructed of an accordion-like, phosphorous bronze tube with copper fittings at each end to facilitate joining with the system tubing. The accordion-like folds in the material are called convolutions.

On some air-conditioning systems, a simple loop is made in the refrigerant tubing itself. The loop permits vibrations to be absorbed in the extended length of tubing.

Liquid Line Sight Glass

The sight glass is a visual indicator used to visually determine the condition of the refrigerant entering the thermal expansion valve. The sight glass is located on the inlet side and as close to the thermal expansion valve as possible. The appearance of the refrigerant passing through the sight glass should be clear. If the sighting indicates a cloudy or milky appearance, the level of refrigerant is low. The milky appearance is caused by tiny refrigerant vapor bubbles mixed with the liquid refrigerant.

Receiver Valve

The receiver valve, referred to as the king valve, is located on the output side of the receiver tank. This valve is used when it is necessary to trap the refrigerant in the receiver and condenser lines.

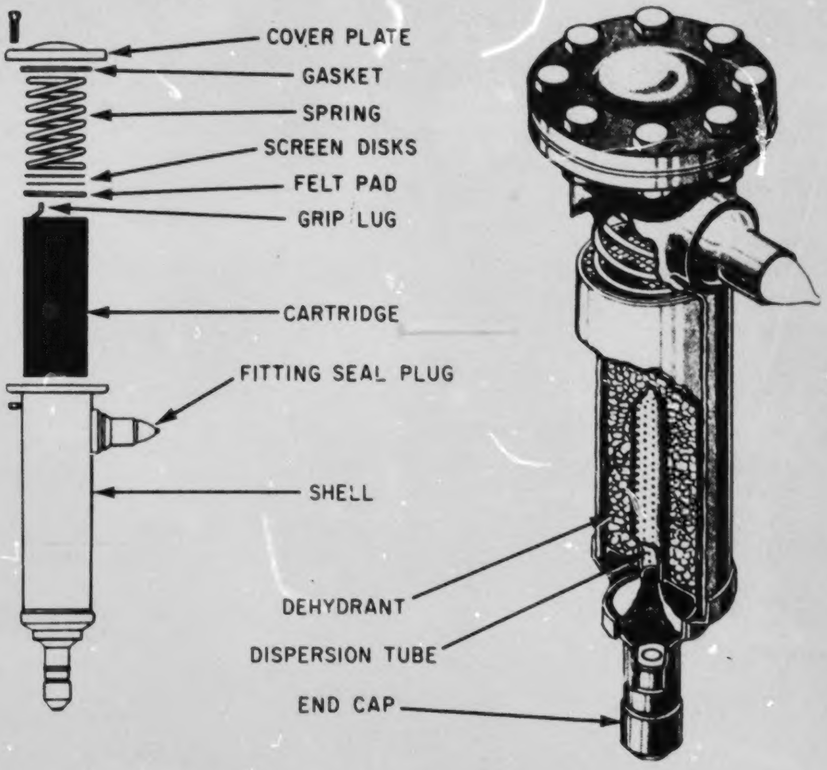
Heat Exchanger

The heat exchanger (fig. 13-1) provides for an increase in system efficiency by transferring heat from the hot liquid (flowing from the receiver to the evaporator) to the cooler suction vapor (flowing from the evaporator to the compressor). Because of this heat transfer, the liquid refrigerant enters the evaporator at a lower temperature, allowing it to absorb more heat-per-pound of refrigerant. This heat transfer also ensures that the vapor flowing to the compressor from the evaporator contains no liquid (which would damage the compressor).

Heat exchangers can be constructed in several ways—a small liquid line enclosed within a larger suction line; a small liquid line wrapped around a larger suction line; or the liquid and suction lines being placed side by side and physically connected together by clamps or solder.

Drier-Strainer (Dehydrator)

The drier-strainer (fig. 13-14), also called a dehydrator, is employed to remove foreign matter and water from the system. Foreign material which would clog small openings, and water which would freeze in the expansion valves, are trapped and held here. The drier-strainer is located in the liquid line



225.191

Figure 13-14.—Drier-strainer (Dehydrator).

between the receiver and the evaporator and consists of a replaceable cartridge of activated alumina or silica gel enclosed in a metal container.

Upon inspection, if the drier strainer feels cooler than the liquid line entering the drier, the indication is that the drier is clogged and the liquid refrigerant is vaporizing in the drier. In this situation, the drier cartridge must be removed and replaced.

CONTROLS

Controls of an air-conditioning unit may be classified into two distinct types—operating and safety. Operating controls maintain the desired conditions, while the safety controls prevent damage to the equipment.

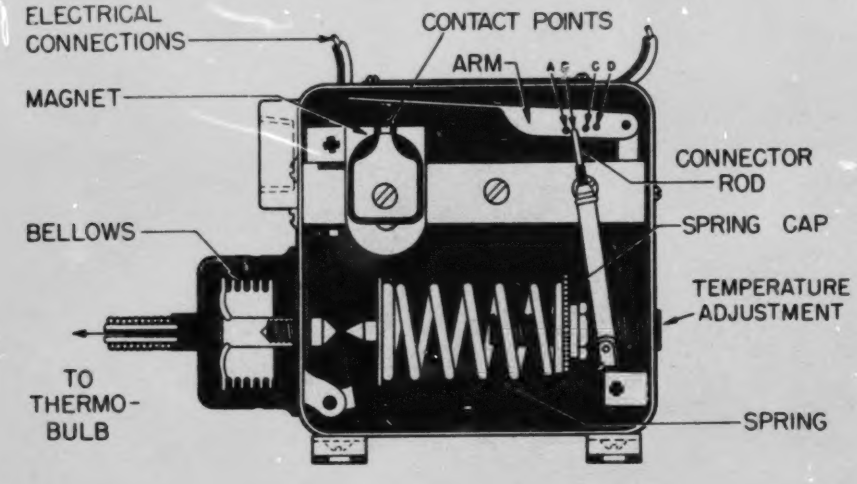
Operating Controls

The operating controls of an air-conditioning system may be simple or complex, depending upon the design and use of the system. Some of the operating controls are manually controlled by the operator, while others are automatic and operate in response to changes in temperature or pressure.

THERMOSTAT.—A thermostat is a device which automatically regulates temperature. Thermostats used on mobile air conditioners, similar to the one shown in figure 13-15, consist of a capillary tube filled with a volatile liquid, a bellows, and a set of electrical contacts.

The thermostat contacts are connected to a solenoid valve circuit, and the capillary tube bulb is placed in the discharge airflow immediately downstream of the evaporator. As the temperature of the discharge air rises, the liquid in the capillary tube expands and exerts a pressure on the bellows. This causes the contacts to close, energizing the solenoid coil which opens the valve so liquid refrigerant can flow to the expansion valve.

When the desired temperature of the discharge air is reached, a reverse of the above action occurs. The liquid in the capillary tube contracts, the contacts open, the solenoid valve closes, and the flow of refrigerant to the expansion valve is stopped.



225.192

Figure 13-15.—Thermostat.

SOLENOID VALVES.—Solenoid valves, similar to the one shown in figure 13-16, are used in mobile air conditioners to control the flow of refrigerant at various points in the system.

These valves are of two types, normally open or normally closed, but regardless of type or use, construction and function of the valves are essentially the same.

In the normally closed type, when the circuit to the solenoid coil is completed, the coil energizes and pulls the valve off its seat, opening the valve passage. When the circuit to the solenoid coil is opened, the coil deenergizes and spring pressure pushes the valve into its seat, closing the valve passage.

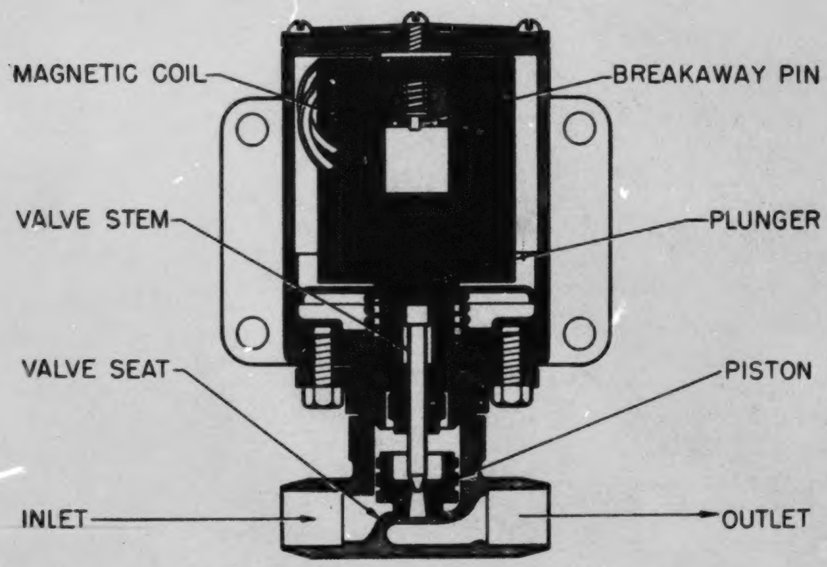
In the normally open type, operation is the reverse of the operation of the normally closed type. When the solenoid coil is energized, the valve is closed; when the solenoid coil is deenergized, the valve is open.

CIRCUIT CONTROLS.—Controls for the various circuits of an air-conditioning unit may vary from simple toggle switches to remote controlled contactor relays. These devices may be used for actuating fans, lights, motors, or for checking various circuits while troubleshooting a defective system. Switches used for maintenance work are called service switches.

Safety Controls

Sufficient safety devices are installed in air-conditioning systems to prevent bodily injury to operating personnel and damage to system equipment or equipment and spaces receiving the conditioned air.

FUSIBLE PLUG.—The fusible plug is provided to prevent an excessive buildup of refrigerant pressure within the confined area of the equipment. The refrigerants commonly used today will act in accordance with the normal liquid/gas laws, whereby increasing temperature



225.193

Figure 13-16.—Solenoid valve.

causes increasing pressure. Should the air-conditioning equipment be in close proximity to a fire, a positive method of releasing vapor and liquid must be provided to prevent the buildup of excessive pressure within the system. The fusible plug is usually located at the inlet connection of the receiver tank. When excessive external heat is present, due to fire or other similar causes, the plug melts, allowing the refrigerant gas to excape from the system. This reduction of gas pressure prevents possible rupture or explosion of the equipment.

HIGH- AND LOW-PRESSURE CUTOUTS.–High- and low-pressure cutout switches are incorporated in refrigeration units to control the operation of the compressor. The pressure control prevents the discharge pressure of the compressor from building up beyond a reasonable limit and suction pressure of the compressor from falling below the safe limit.

The control unit illustrated in figure 13-17 contains controls for both the high- and low-pressure gages. In some installations the high- and low-pressure controls are mounted in separate units; however, their operation is essentially the same.

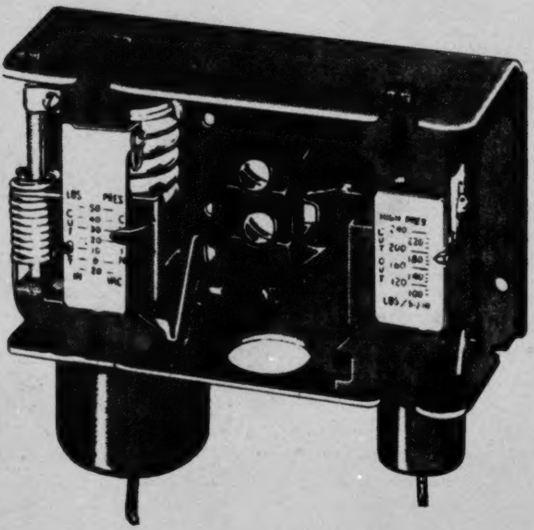


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Figure 13-17.–High- and low-pressure cutouts.

DUCT AIR PRESSURE SWITCH.–The duct air pressure switch is designed to shut down the entire unit if an overpressure condition occurs in the conditioned-air discharge duct. The pickup tube for the duct pressure switch is located in the discharge air plenum chamber.

MOBILE AIR CONDITIONER (NR-5C)

The NR-5C mobile air conditioner (fig. 13-18) is a mobile, trailer-mounted, electrically powered, self-contained air conditioner. It requires a 440-volt, 3-phase, 60-Hz power supply for operation of the compressor motor, fan motor, and control circuits.

The NR-5C has a cooling capacity of 22 tons with a discharge air temperature of 45° F in the cooling mode of operation, and of 90° F in the dehumidification mode of operation. It will operate in a temperature range of 0° to 110° F at altitudes up to 5,000 feet.

The NR-5C is designed to provide cooling, ventilation, dehumidification, and filtration of air for electronic equipment. The unit is intended for, but not limited to, use for conditioning aircraft cabins and equipment compartments.

The NR-5C utilizes a semihermetic, six-cylinder compressor, with refrigerant R-22 used as the heat transfer medium. An electrically actuated unloader device is provided to enable the compressor to operate on as few as two cylinders. This device is controlled by temperature controls that will operate the unloader solenoids to unload the compressor whenever the cooling air temperature drops below a set temperature.

The NR-5C utilizes a condenser fan (fig. 13-19) that sends an air flow across two condenser coils. This provides the means of condensing the hot refrigerant gas flowing from the compressor. (See fig. 13-20.) If the head

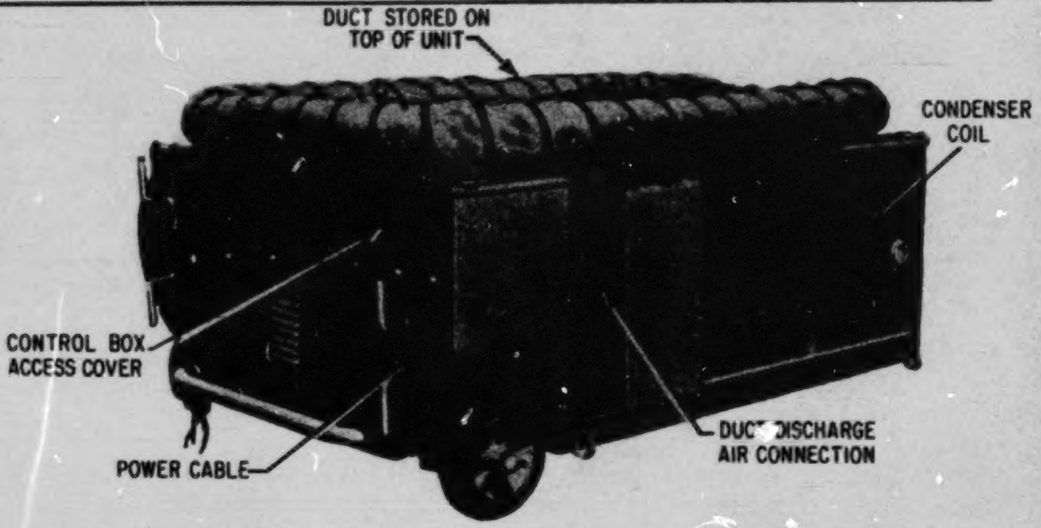

DUCT STORED ON TOP OF UNIT
CONDENSER COIL
CONTROL BOX ACCESS COVER
POWER CABLE
DUCT DISCHARGE AIR CONNECTION

Figure 13-18.—NR-5C air conditioning unit, 3/4 right rear view. 225.16

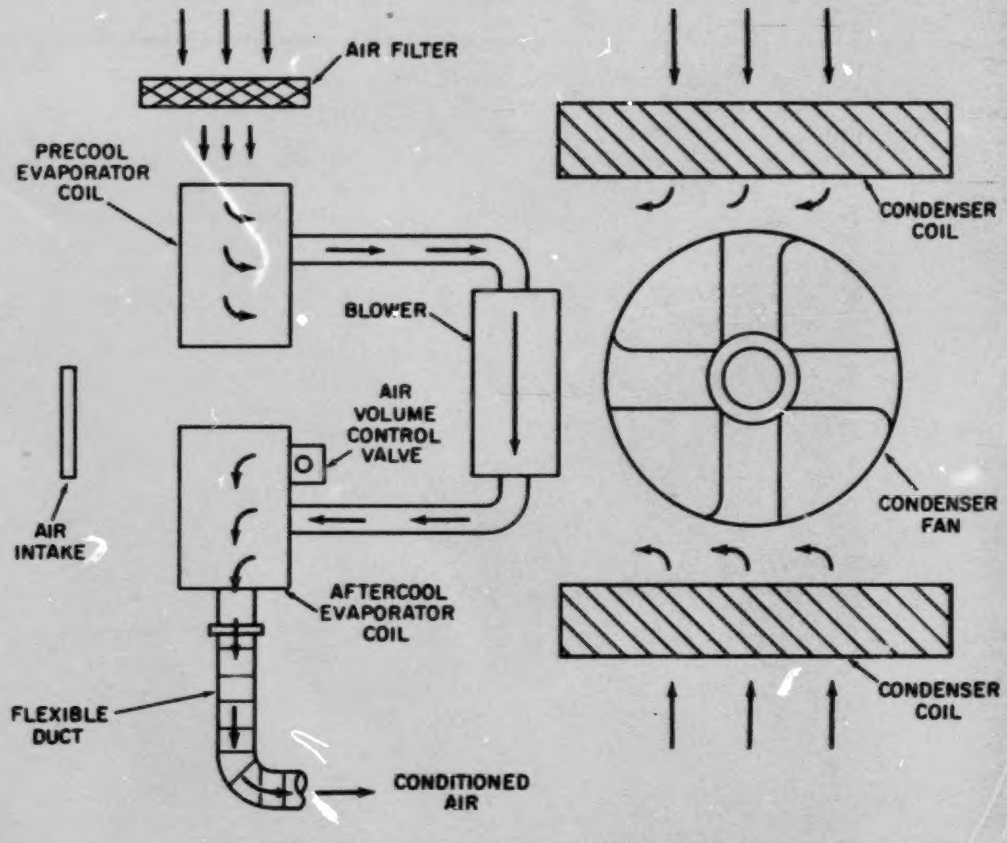
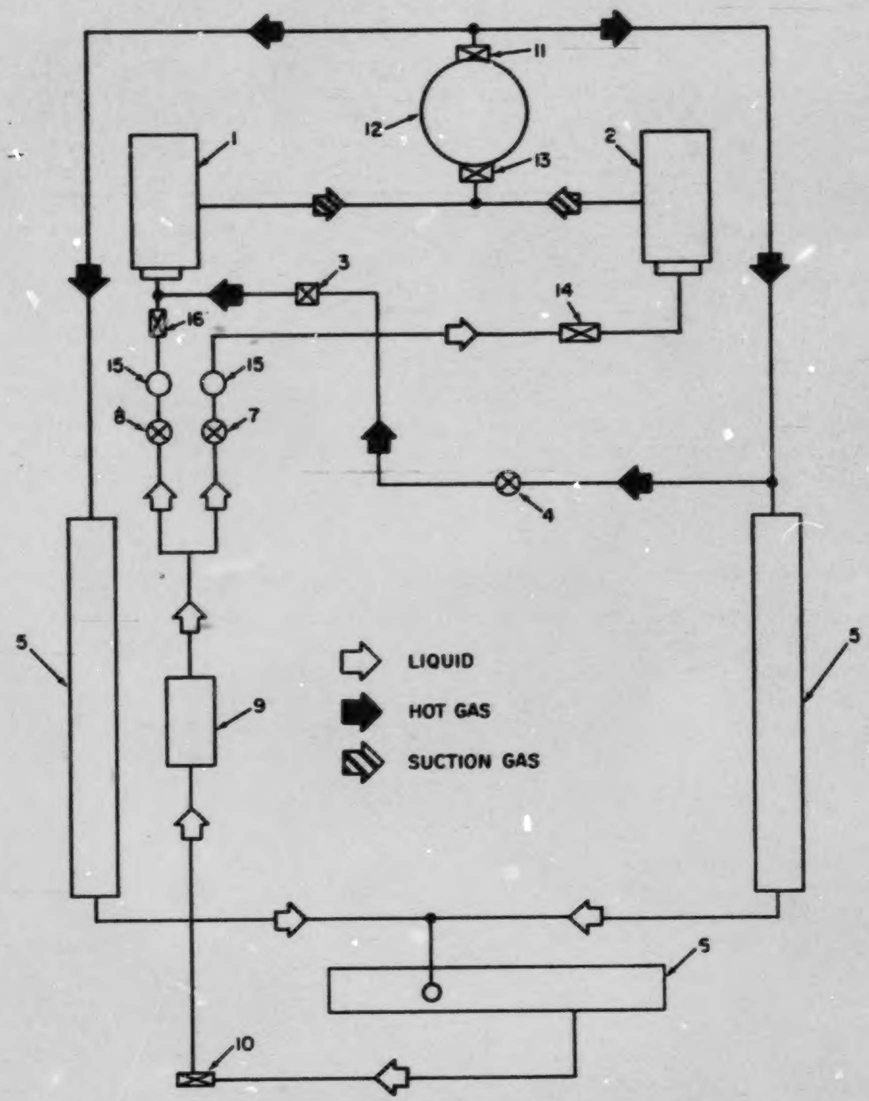

AIR FILTER
PRECOOL EVAPORATOR COIL
CONDENSER COIL
BLOWER
AIR VOLUME CONTROL VALVE
AIR INTAKE
CONDENSER FAN
AFTERCOOL EVAPORATOR COIL
CONDENSER COIL
FLEXIBLE DUCT
CONDITIONED AIR

Figure 13-19.—Condenser and conditioned air flow schematic diagram. 227.87


11
12
1
13
2
3
14
16
15
15
8
7
4
5
5
9
LIQUID
HOT GAS
SUCTION GAS
5
10

1. **Aftercool evaporator coil**
2. **Precool evaporator coil**
3. **Aftercool hot gas bypass valve**
4. **Aftercool hot gas solenoid valve**
5. **Condenser (2)**
6. **Liquid receiver**
7. **Precool refrigerant solenoid valve**
8. **Aftercool refrigerant solenoid valve**
9. **Filter-drier**
10. **Receiver shutoff valve**
11. **Compressor discharge valve**
12. **Compressor**
13. **Compressor suction valve**
14. **Precool expansion valve**
15. **Sight glass (2)**
16. **Aftercool expansion valve**

227.88

Figure 13-20.—Refrigerant flow schematic diagram.

pressure drops to 140 psi, the condenser fan will cut out to reduce the amount of condensing.

Two tube and fin evaporator coils shown in figure 13-19 are incorporated in the air conditioner. One precools the air as it enters the unit; the other cools the air to the required temperature as it leaves the blower. A manual air volume control valve regulates the flow of conditioned air from the aftercool evaporator from one to three psi.

SYSTEM OPERATION

The NR-5C is composed of 3 major systems–electrical, refrigerant, and airflow. (See figures 13-19, 13-20, and 13-21.)

Since the electrical and refrigerant systems are interconnected and depend upon each other for operation, they are discussed together.

Electrical/Refrigerant Systems

Operation and control functions require 440-volt, 3-phase, 60-Hz power connected to the unit by a power cable. This power cable is connected at the rear of the unit. From the receptacle, the power is carried through the 100-amp circuit breaker. The full 440 volts is sent to the motor starters. A 200-VA transformer is used in the circuit to lower the voltage from 440 volts ac to 110 volts ac for control and instrument operation.

Placing the circuit breaker (figure 13-22) in the ON position connects power to the circuits and illuminates the power ON light. The electrical/refrigerant functions are started by placing the selector switch (figure 13-22) in the COOL or DEHUM (dehumidify) position.

COOLING MODE.–The cooling mode is initiated when the selector switch is set to the cool position (fig. 13-22). The compressor starts operating by closing cooling relay R1, and the compressor motor starter holding coils M1 and M2 are energized (see fig. 13-21) when the circuit through high-pressure and low-pressure switches (HP and LP), compressor safety relay R3, motor relay R4, and pump down relay R5 are actuated, then the cool circuit is in operation. The blower motor starter contacts are closed, starting the motor, and the condenser fan motor is energized.

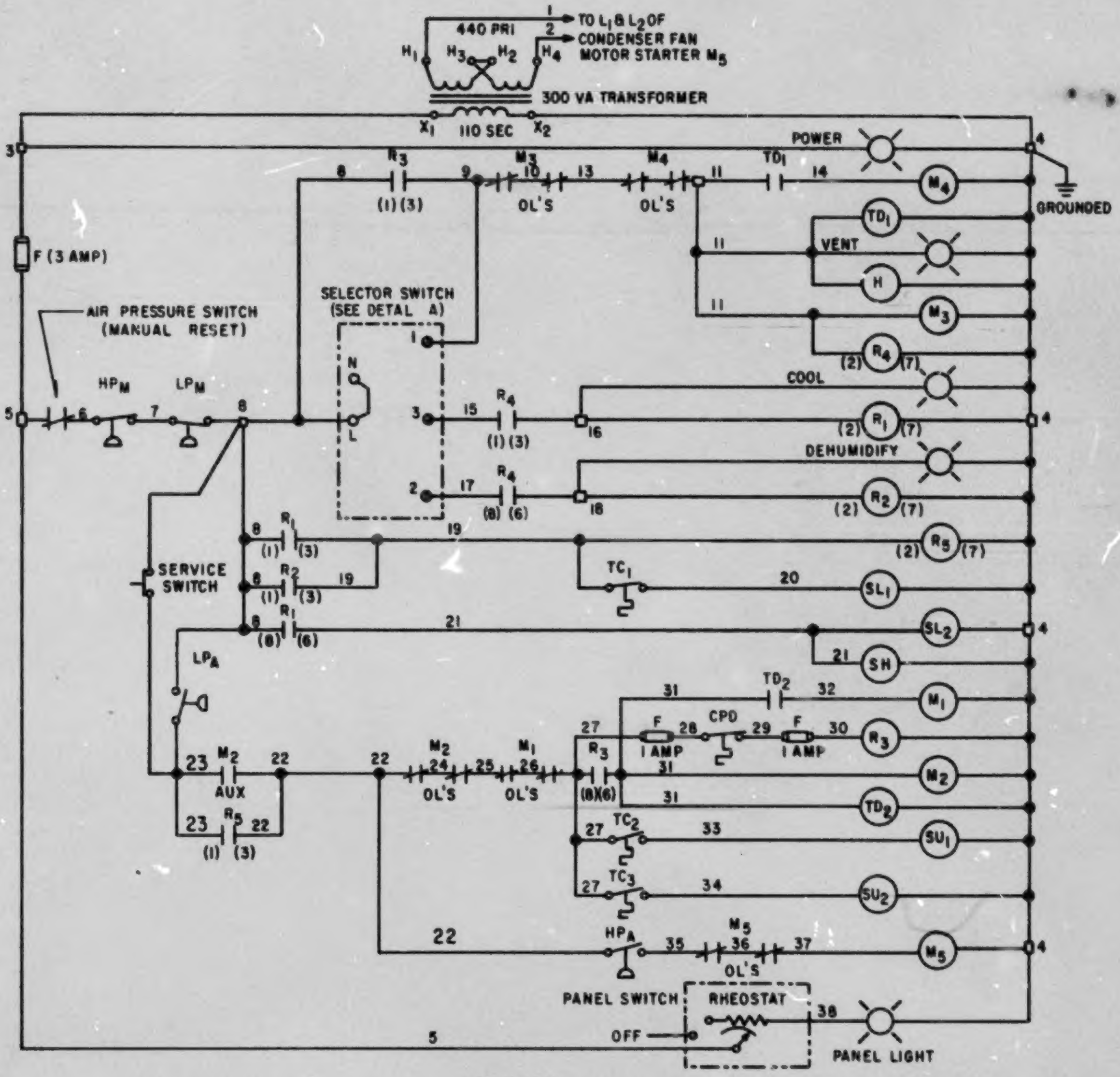
With the compressor operating (fig. 13-20), the superheated refrigerant vapor leaves the compressor (12) through the compressor discharge valve (11) to the condensers (5). The condensing airflow is provided by the condenser fan (fig. 13-19). This fan is controlled by switch HP_A (fig. 13-21). If the head pressure falls below 140 psi, the fan will cut out to decrease the amount of condensing. As the ambient or entering air temperature rises, forcing the head pressure to increase the condensing, the fan will return to operation at 220-psi head pressure.

NOTE: Compressor discharge and suction pressures are monitored on gages mounted on the instrument panel (fig. 13-22).

The superheated refrigerant vapor is changed to a liquid in the condenser. This liquid is stored in the receiver (6, fig. 13-20), and from the receiver the liquid passes through the filter-drier (9). From the filter-drier the liquid passes through the precool and aftercool solenoid valves (7 and 8) and sight glasses (15). The two expansion valves (14 and 16) meter the liquid into the two evaporator coils (1 and 2). From the evaporator coils the suction gas returns to the compressor through the suction valve (13).

As the air to be conditioned flows through the fins of the precool evaporator, it is lowered in temperature as required by the setting of the precool thermostat (TC1, fig. 13-21). If the entering air temperature is sufficiently low and no precooling is required, the thermostat (TC1) will open its contacts, deenergize the precool refrigerant solenoid valve (7 fig. 13-21), and stop the flow of refrigerant to the precool evaporator.

Temperature of the conditioned air leaving the aftercool evaporator is controlled by a two-stage switch (TC2 and TC3, fig. 13-21). When the temperature of the conditioned air drops below the control setting, TC2 opens and deenergizes one unloader solenoid (SU1, fig. 13-21). This stops compression on one bank of pistons in the compressor and cuts down compressor capacity. As the temperature drops further, TC3 opens and deenergizes the second unloader solenoid (SU2, fig. 13-21) to further decrease compressor capacity.


TO L_1 & L_2 OF CONDENSER FAN MOTOR STARTER M_5
440 PRI
H_1 H_3 H_2 H_4
300 VA TRANSFORMER
X_1 110 SEC X_2
POWER
GROUNDED
F (3 AMP)
AIR PRESSURE SWITCH (MANUAL RESET)
HP_M
LP_M
SELECTOR SWITCH (SEE DETAL A)
N
L
R_3
M_3
M_4
TD_1
OL'S
VENT
H
COOL
DEHUMIDIFY
R_1 R_2 R_4 R_5
TC_1
SL_1 SL_2 SH
SERVICE SWITCH
LP_A
TD_2
CPD
F 1 AMP
M_1 M_2
AUX
TC_2 TC_3
SU_1 SU_2
HP_A
M_5
PANEL SWITCH
RHEOSTAT
OFF
PANEL LIGHT

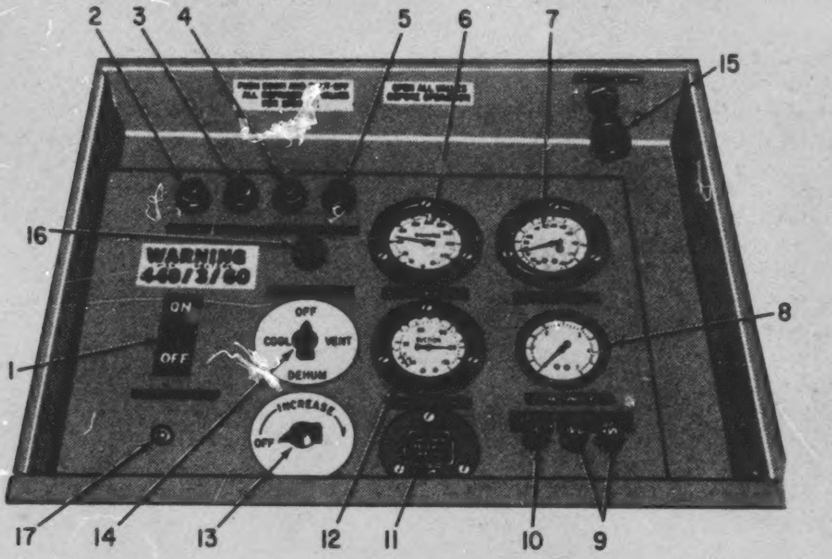
LEGEND

M_1 & M_2—COMPRESSOR STARTER HOLDING COIL
M_3 & M_4—BLOWER MOTOR STARTER HOLDING COIL
M_5——CONDENSER FAN MOTOR STARTER HOLDING COIL
HP——HIGH PRESSURE M-MANUAL A-AUTOMATIC
LP——LOW PRESSURE M-MANUAL A-AUTOMATIC
R——RELAY-R_1-COOL, R_2-DEHUMIDIFY, R_3-COMPRESSOR SAFETY R_4-MOTOR INTERLOCK, R_5-PUMP DOWN
SL——SOLENOID LIQUID 1-PRECOOL 2-AFTERCOOL

SU—SOLENOID COMPRESSOR UNLOADER 1 & 2 STAGES
SH—SOLENOID HOT GAS-AFTERCOOL
TC—TEMPERATURE CONTROL TC_1-PRECOOL ENTERING AIR TC_2-& TC_3—UNIT-LEAVING AIR
F—FUSE
OL—MOTOR THERMAL OVERLOAD
CPD—COMPRESSOR INTERNAL PROTECTIVE DEVICE
H—HOUR METER ELAPSE TIME TD_1 & TD_2 TIME DELAY RELAY

227.89

Figure 13-21.—NR-5C air conditioning unit electrical system.



1. Circuit Breaker
2. Power on light
3. Vent circuit light
4. Cool circuit light
5. Dehumidify circuit light
6. Discharge pressure gage
7. Air temperature gage
8. Air pressure gage
9. Compressor fuses (1 amp)
10. Control fuse (5 amp)
11. Hourmeter
12. Suction Pressure gage
13. Panel light switch
14. Selector Switch
15. Air volume control
16. Panel light
17. Service switch

227.90

Figure 13-22.—Instrument panel.

DEHUMIDIFICATION MODE.—See figure 13-21. When the selector switch is placed in the dehumidfy position, the dehumidify circuit light illuminates. Operation of the refrigerant system is the same as explained above except that the cool relay (R1) deenergizes, closing the aftercool refrigerant solenoid valves, and stops refrigerant flow through the aftercool evaporator.

The air to be conditioned enters and flows through the fins of the precool evaporator where the temperature is lowered to the setting of the thermostat (TC1), and the moisture content is lowered by condensation of moisture on the cool evaporator tubes. The air is then compressed in the blower. Compression causes the air to be heated to the dehumidification temperature, after which it is delivered to the conditioned space at approximately 90° F.

VENTILATION MODE.—When the selector switch is placed in vent position, the vent light illuminates. Due to the holding action of the pumpdown relay (R5, fig. 13-21), the refrigerant system continues to operate for a period of time when switched from the cool or dehumidification modes to the vent mode. With the refrigerant solenoid valves closed (7 and 8, fig. 13-20) the compressor attempts to evacuate the low-pressure side of the system. When low-side pressure drops below 20 psi (pumpdown completed) the low-pressure cutout switch (LPM, fig. 13-21) opens the circuit to the compressor motor starter, halting the compressor.

Airflow

See figure 13-19. Ambient air enters the unit through a 50-micron absolute filter and passes through the precool coil. If the dewpoint temperature of the ambient air should exceed the temperature of the leaving air, the excess moisture will condense on the coil. Because of this, the moisture content of the delivered air will never exceed that of saturated air at the precool coil. The "leaving" temperature at the precool coil is 45° F. This air is drawn through flexible ducting into the positive displacement blower which is driven by a 30-horsepower motor through a belt drive.

This blower compresses 100 pounds of air per minute to 3 psig. This compression adds sensible heat to the air, raising its temperature but leaving the moisture content unchanged. As this heated air passes through the after-cool evaporator coil, it is cooled to its final temperature. Air leaves the unit at a temperature of 45° F and relative humidity of 80%. A duct air pressure switch will stop operation of the unit when the conditioned air pressure exceeds 5.0 psig.

See figure 13-19. Air is moved across the condenser coils by an axial-flow, propeller-type fan for condensing the air flow. The fan is directly connected to its drive motor and is controlled by compressor head pressure. As the compressor head pressure drops, it will actuate a pressure switch which cycles the fan and provides more or less condensation of the refrigerant.

TROUBLESHOOTING

Not all of the possible troubles that might be encountered in conjunction with the NR-5C can be covered here; however, table 13-1 lists the troubles most likely to be encountered, probable causes for each trouble, and the remedy.

MAINTENANCE

Maintenance data for the air conditioner includes information for servicing, testing, adjusting, and lubricating. Applicable safety precautions and first aid information are also included. For more maintenance information, refer to the Operation and Service Instructions for the NR-5C mobile air conditioner.

MOBILE AIR CONDITIONER (NR-10)

The NR-10 air conditioner (fig. 13-23) is a mobile, trailer-mounted, self-contained unit. It is powered by a 82-horsepower diesel engine and utilizes a 6-cylinder, open-type refrigerant compressor.

The NR-10 has a cooling capacity of 19 tons with a discharge air temperature of 45° (±5°) F in the cooling mode of operation, and 90° F minimum in the dehumidification mode of operation. It will operate in a temperature range of 0° to 110° F at altitudes up to 5,000 feet.

The NR-10 is designed to provide cooling, ventilation, dehumidification, and filtration of air for electronic equipment. The unit is intended for, but not limited to, use for air conditioning aircraft cabins and equipment compartments.

The NR-10 utilizes an open-type, six-cylinder compressor, with refrigerant R-22 used as the heat exchange medium. An unloader device is provided to enable the compressor to operate on as few as two cylinders. The unloader, a pressure-sensing device, senses any variation in refrigerant suction pressure and unloads or loads, as required, the individual cylinders to maintain a constant pressure.

The refrigerant compressor is driven by the diesel engine through a flexible coupling and a magnetic clutch. The clutch is electrically actuated and may be engaged or disengaged at any speed between 1,200 and 1,800 rpm.

Condensing air flow is provided by a belt-driven, axial-type, condenser fan. The fan is

Table 13-1.—Troubleshooting

Trouble	Possible cause	Remedy
Panel light fails to illuminate.	Defective lamp.	Replace lamp.
	Defective PANEL LIGHT switch.	Replace switch
	Defective panel light.	Replace panel light.
	Defective wiring.	Check and repair wiring.
Circuit light(s) fail to illuminate.	Defective lamp(s).	Replace lamp(s).
	Defective SELECTOR SWITCH.	Replace switch.
	Defective light(s).	Replace light(s).
	Defective wire.	Check and repair wiring.
Unit cuts out on high pressure.	High pressure cutout switch tripped.	Reset switch.
	High pressure cutout switch improperly set.	Adjust switch setting.
	High pressure switch defective.	Replace switch.
Compressor fails to start.	High or low pressure cutout tripped.	Reset switch.
	Defective high or low pressure cutout.	Replace switch.
	Compressor motor starter tripped.	Reset motor starter.
	Defective motor starter.	Replace motor starter.
	Defective relay.	Replace relay.
	Defective wiring.	Check and repair wiring.
	Defective compressor.	Repair or replace compressor.

Talbe 13-1.–Troubleshooting-Continued

Trouble	Possible cause	Remedy
DISCHARGE PRESSURE gage indicates less than 200 psi.	Refrigerant charge low as indicated by bubbles in sight glass.	Test system for leaks, then add refrigerant as required.
	Defective hot gas bypass solenoid valve.	Replace solenoid valve.
	Defective gage.	Replace gage.
	Defective compressor or unloader.	Repair or replace compressor.
DISCHARGE PRESSURE gage indicates higher than 365 psi.	Condenser coil clogged or obstructed.	Clean coil.
	Overcharge of refrigerant.	Bleed small amounts of refrigerant from suction valve through a charging line until pressure is normal.
	Defective gage.	Replace gage.
	Defective compressor.	Repair or replace compressor.
	Receiver shutoff valve closed.	Open valve.
SUCTION PRESSURE gage indicates zero psi.	Receiver shutoff valve closed.	Open valve.
	Defective gage.	Replace gage.
	Defective compressor.	Repair or replace compressor.
SUCTION PRESSURE gage indicates less than 40 psi.	Air filter dirty.	Clean air filter.
	Evaporator coil frosted, blocking airflow.	Turn off unit and allow ice to melt.

Table 13-1.—Troubleshooting-Continued

Trouble	Possible cause	Remedy
	Low refrigerant charge.	Add refrigerant.
	Filter-drier clogged.	Replace filter drier core.
	Expansion valve defective.	Repair or replace expansion valve.
	Hot gas bypass valve not functioning properly.	Adjust valve. Replace valve if necessary.
	Blower not operating properly.	Repair or replace blower.
Suction pressure higher than normal.	Hot gas bypass valve set too high.	Adjust bypass valve.
	Discharge pressure too high.	Refer to (6 above).
	Expansion valve not operating properly.	Adjust expansion valve.
	Defective compressor.	Repair or replace compressor.
Blower not operating.	Air pressure switch tripped.	Reset switch.
	Defective air pressure switch.	Replace switch.
	Defective blower motor.	Replace blower motor.
	Defective wiring.	Check wiring in unit and repair as necessary.
	Defective blower.	Repair or replace blower.

Table 13-1.–Troubleshooting-Continued

Trouble	Possible cause	Remedy
Unit will not start.	Air pressure switch tripped.	Reset switch.
	High- or low-pressure switch tripped.	Reset switches as necessary.
	3-amp fuse blown.	Replace fuse.
	Defective relay.	Replace relay.
Compressor will not start.	Pressure switch tripped.	Reset switch.
	Defective relay.	Replace relay.
	Compressor motor starter tripped.	Reset motor starter.
	Defective motor starter.	Repair or replace motor starter.
	Compressor internal thermostat switch tripped.	Allow compressor to cool. Switch will reset.
	1-amp fuse blown.	Replace fuse.
	Defective compressor.	Repair or replace compressor.
Condenser fan motors will not start.	Pressure switches open.	Allow discharge pressure to reach switch settings.
	Pressure switches not operating properly.	Adjust switches. Replace switches if necessary.
	Fan motor starter(s) tripped.	Reset motor starter(s).
	Defective motor starter(s).	Repair or replace motor starter(s).

Table 13-1.—Troubleshooting-Continued

Trouble	Possible casue	Remedy
System will not pump down.	Defective receiver shutoff valve.	Replace shutoff valve.
	Defective pumpdown relay.	Replace relay.
	Defective pressure switch.	Replace pressure switch.
	Solenoid valves will not close.	Repair or replace solenoid valves.
Compressor will not unload.	Conditioned air two-stage switch not set properly.	Adjust switch.
	Defective switch.	Replace switch
	Defective unloader solenoids.	Replace solenoids.
	Defective wiring.	Repair or replace wiring.

driven by the diesel engine through a set of pulleys and two drive belts. The condensing air flow is moved across two condenser coils that provide a means to condense the hot gaseous refrigerant flowing from the refrigerant compressor.

Evaporator air flow is provided by a belt-driven, centrifugal, evaporator fan. The fan is driven by the diesel engine through a set of pulleys and four drive belts. The fan provides all the air necessary for ventilating, cooling, and dehumidifying by creating air flow across a tube and fin evaporator coil to provide conditioned air.

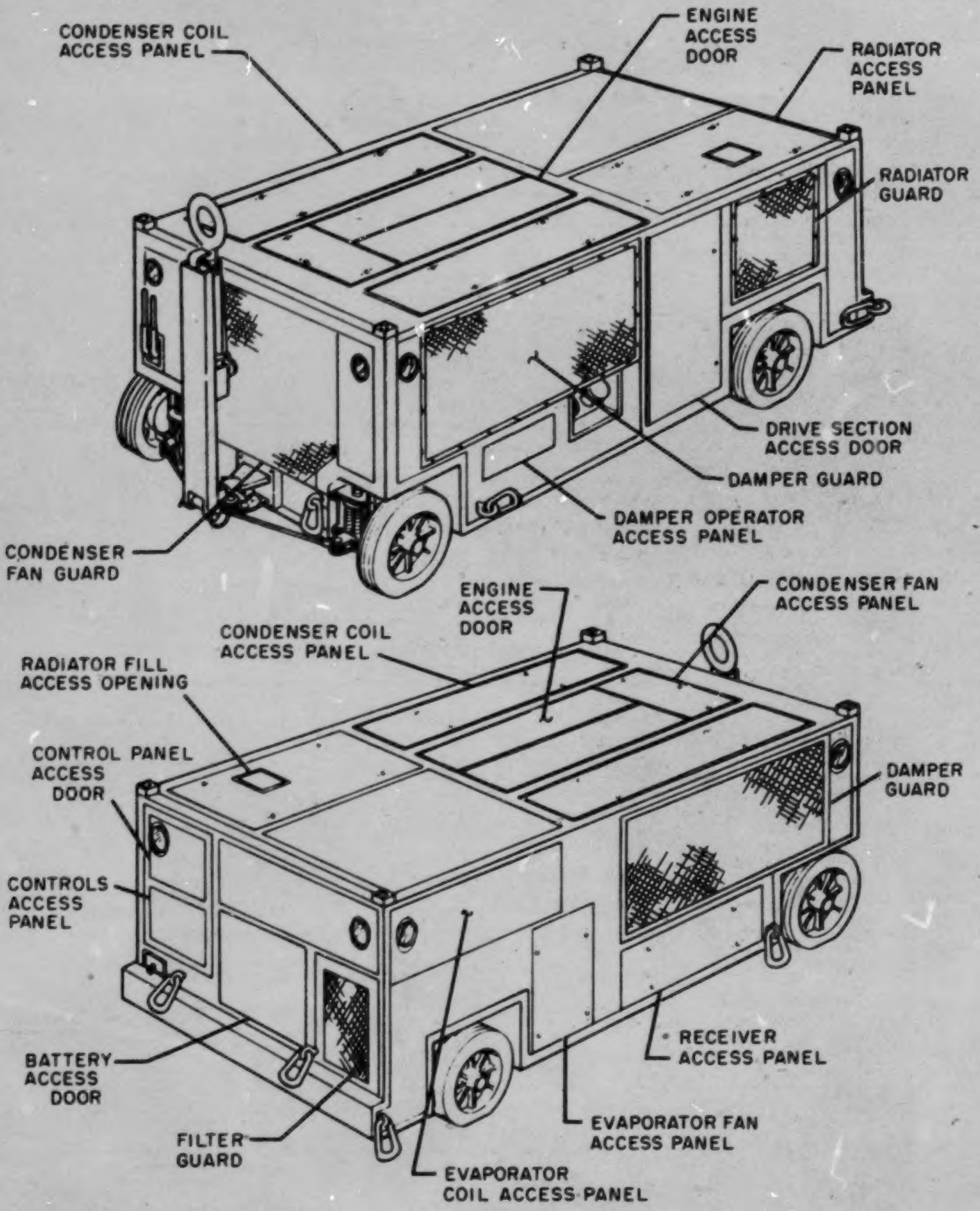
A liquid-to-air transfer reheat coil is utilized by the NR-10 to reheat dehumidified air and is installed in series with the evaporator coil. This reheat coil utilizes the engine coolant.

SYSTEM OPERATION

The NR-10 is composed of 5 major systems—electrical and control, fuel and lube oil, water, air flow, and refrigerant. In order for the ASM to become familiar with the operation of the NR-10 air conditioner, each system is discussed in the following sections.

Electrical and Control

Power for operation of the electrical and control system (fig. 13-24) is provided by two 24-dc batteries or external power source to start the unit. Once in operation, the power is provided by the engine generator and regulated by a voltage regulator.

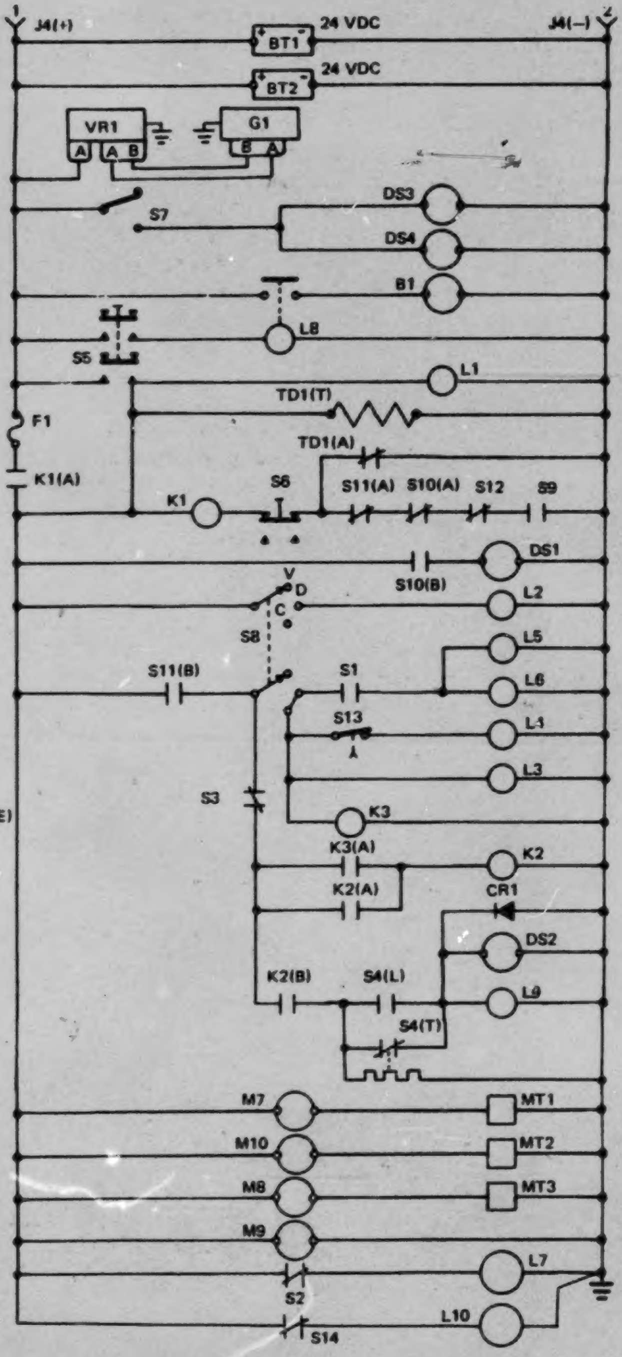

CONDENSER COIL ACCESS PANEL
ENGINE ACCESS DOOR
RADIATOR ACCESS PANEL
RADIATOR GUARD
DRIVE SECTION ACCESS DOOR
DAMPER GUARD
DAMPER OPERATOR ACCESS PANEL
CONDENSER FAN GUARD
ENGINE ACCESS DOOR
CONDENSER FAN ACCESS PANEL
CONDENSER COIL ACCESS PANEL
RADIATOR FILL ACCESS OPENING
CONTROL PANEL ACCESS DOOR
DAMPER GUARD
CONTROLS ACCESS PANEL
RECEIVER ACCESS PANEL
BATTERY ACCESS DOOR
FILTER GUARD
EVAPORATOR FAN ACCESS PANEL
EVAPORATOR COIL ACCESS PANEL

224.122

Figure 13-33.—Model NR-10 mobile air conditioning unit.

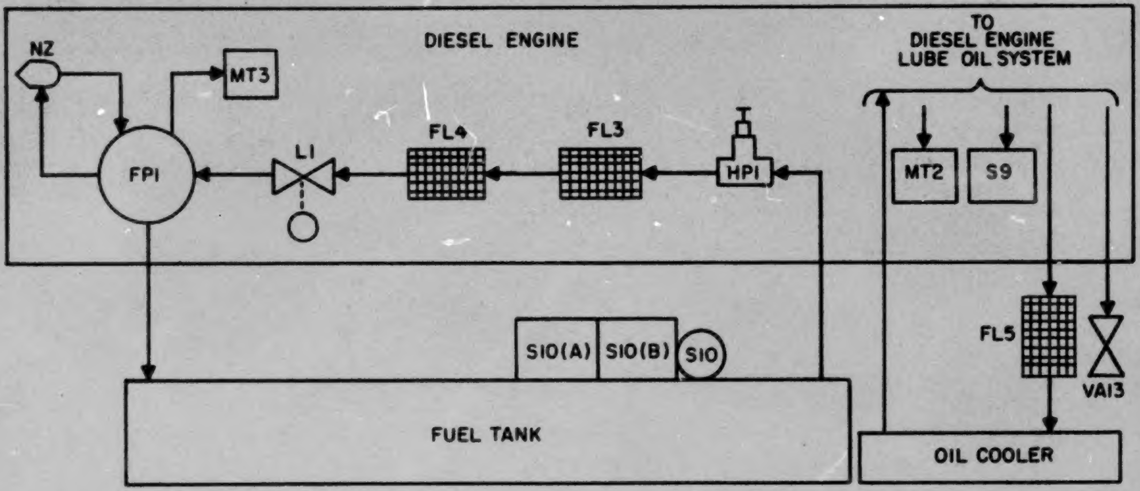
NOTE
ALL GROUNDS (CHASSIS, ENGINE, AND EXTERNAL POWER) ARE SHOWN AS COMMON.

BT1	BATTERY
BT2	BATTERY
B1	STARTER MOTOR
CR1	DIODE
DS1	LOW FUEL WARNING LIGHT
DS2	COMPRESSOR LIGHT
DS3	PANEL LIGHT
DS4	PANEL LIGHT
F1	FUSE
G1	GENERATOR
J4	EXT PWR RECEPTACLE
K1	CONTROL CIRCUIT RELAY
K2	PUMPDOWN RELAY
K3	COOLING RELAY
L1	FUEL SOLENOID VALVE
L2	HEAT COIL SOLENOID VALVE
L3	PUMPDOWN SOLENOID VALVE
L4	COOLING SOLENOID VALVE
L5	HOT GAS BYPASS SOLENOID VALVE
L6	QUENCH LINE SOLENOID VALVE
L7	SOLENOID DUMP VALVE
L8	STARTER SOLENOID
L9	MAGNETIC CLUTCH
L10	SOLENOID DUMP VALVE
MT1	WATER TEMPERATURE TRANSMITTER
MT2	LUBE OIL PRESSURE TRANSMITTER
MT3	FUEL OIL PRESSURE TRANSMITTER
M7	WATER TEMPERATURE GAGE
M8	FUEL OIL PRESSURE GAGE
M9	BATTERY/GENERATOR INDICATOR
M10	LUBE OIL PRESSURE GAGE
S1	PRESSURE DIFFERENTIAL SWITCH
S2	PRESSURE SWITCH
S3	HIGH/LOW PRESSURE CUTOUT SWITCH
S4(L)	COMPRESSOR OIL CUTOUT (LOW PRESSURE)
S4(T)	COMPRESSOR OIL CUTOUT (2-MINUTE TIME DELAY)
S5	START SWITCH
S6	STOP SWITCH
S7	PANEL LIGHT SWITCH
S8	SELECTOR SWITCH
S9	LOW LUBE OIL PRESSURE SWITCH
S10(A)	LOW LEVEL CUTOUT SWITCH
S10(B)	LOW FUEL WARNING SWITCH
S11(A)	DIESEL OVERSPEED SWITCH
S11(B)	DIESEL INTERLOCK SWITCH
S12	DIESEL HIGH TEMPERATURE CUTOUT SWITCH
S13	COOLING THERMOSTAT
S14	PRESSURE SWITCH
TD1	TIME DELAY RELAY
VR1	VOLTAGE REGULATOR


1
J4(+)
BT1
24 VDC
J4(–)
2
BT2
24 VDC
VR1
A
A B
G1
B A
DS3
S7
DS4
B1
L8
S5
L1
TD1(T)
F1
TD1(A)
K1(A)
S6
K1
S11(A)
S10(A)
S12
S9
DS1
S10(B)
V
D
C
L2
S8
L5
S11(B)
S1
L6
S13
L4
L3
S3
K3
K3(A)
K2
K2(A)
CR1
DS2
K2(B)
S4(L)
L9
S4(T)
M7
MT1
M10
MT2
M8
MT3
M9
L7
S2
L10
S14

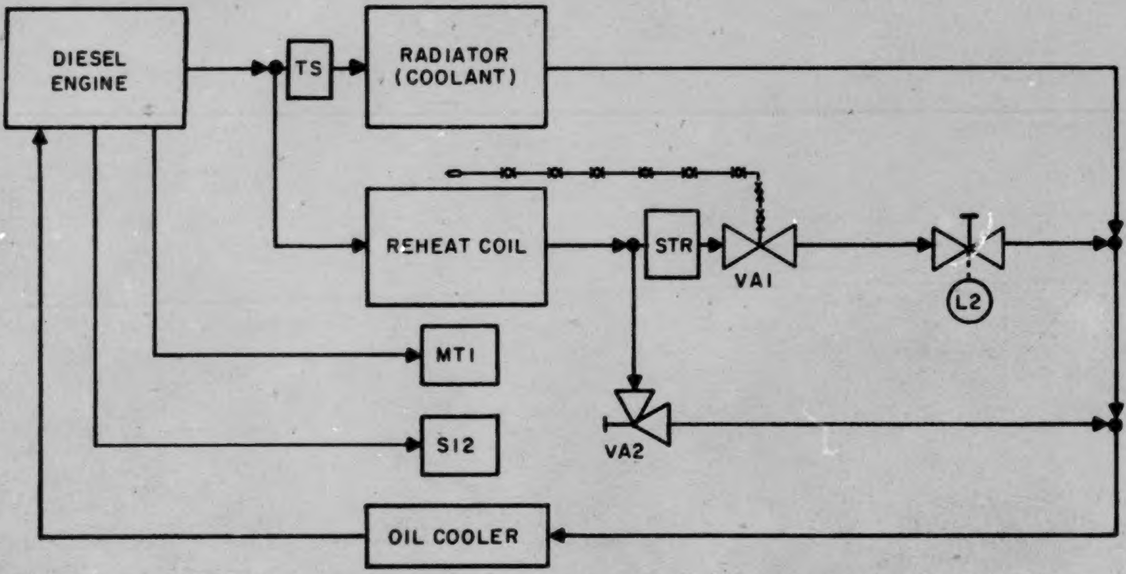
224.145

Figure 13-24.—Electrical schematic.


NZ
MT3
DIESEL ENGINE
TO DIESEL ENGINE LUBE OIL SYSTEM
FPI
L1
FL4
FL3
HPI
MT2
S9
FL5
VA13
S10(A)
S10(B)
S10
FUEL TANK
OIL COOLER

224.151

Figure 13-25.—Fuel and lube oil flow diagram.


DIESEL ENGINE
TS
RADIATOR (COOLANT)
REHEAT COIL
STR
VA1
L2
MT1
S12
VA2
OIL COOLER

L2	HEAT COIL SOLENOID VALVE
MT1	WATER TEMPERATURE TRANSMITTER
STR	STRAINER
S12	HIGH TEMPERATURE CUTOUT SWITCH
TS	THERMOSTAT
VA1	WATER REGULATOR VALVE
VA2	BYPASS VALVE

224.152

Figure 13-26.—Water function flow diagram.

Fuel and Lube Oil

With the fuel solenoid valve (fig. 13-25) open and the engine operating, fuel is drawn through the hand primer, primary and secondary fuel filters, and the fuel solenoid valve.

The fuel pressure transmitter senses fuel pressure and transmits a signal to the fuel pressure gage. This gage, installed on the fuel tank, incorporates two float switches. A low-level warning switch actuates the low fuel light on the instrument panel; and a low-level cutout switch will cause the engine to shut down in the event of low fuel supply.

The lube oil system (fig. 13-25) will prevent the unit from starting until sufficient oil pressure is attained and will also shut down the air conditioner in the event of low oil pressure.

Water System

Three separate requirements are fulfilled by the air-conditioner water system (fig. 13-26)—engine cooling, lube oil cooling, and reheating of air during the dehumidification mode.

In the ventilation and cooling modes of operation, the water function operates as follows. Coolant leaves the engine and passes through the radiator. From the radiator, the coolant passes through the lube oil cooler and back to the engine. A small amount of coolant passes through the reheat coil and bypass valve. The coolant that passes through the bypass valve maintains the required reheat during the cooling mode of operation. When the air conditioner is in the dehumidification mode, the water solenoid valve opens to allow maximum flow through the reheat coil.

Airflow

Airflow is provided by the axial-type condenser fan and the centrifugal evaporator fan (fig. 13-27). The condenser fan provides air for both condensing and engine cooling. Condensing air is drawn through pressure controlled dampers that operate in response to refrigerant pressure. The air passes across the tube and condenser coils, where it condenses the hot gaseous refrigerant leaving the refrigerant compressor.

Conditioned air is provided by the evaporator fan, drawing in fresh air through the air filter on the rear of the unit. This air then passes across the evaporator coil and reheat coil. A solenoid-operated dump valve and pressure switch are provided to prevent surging when conditioned air delivered from the air conditioner is between 30 and 70 pounds per minute.

Refrigerant System

The air-conditioner refrigerant operation (fig. 13-28) is initiated when the selector switch (fig. 13-29) is positioned to COOL or DEHUM. Continued operation is maintained with the selector switch also set to VENT until the system pumps down. Operation of the refrigerant modes is explained in the following paragraphs.

COOLING MODE.—The cooling mode is initiated when the selector switch (figure 13-29) is set to COOL. Hot refrigerant gas leaves the compressor at the discharge valve and passes through the condenser coils and to the refrigerant receiver. Condensation of the gaseous refrigerant is controlled by damper operators that sense refrigerant discharge pressure at the receiver output. From the receiver the refrigerant, now a high-pressure liquid, passes through the filter-drier and the liquid-suction heat exchanger, where it is cooled by low-pressure refrigerant gas from the evaporator coil. Upon leaving the liquid-suction heat exchanger, the refrigerant passes through the pumpdown and cooling solenoid valves and moisture indicators to the pumpdown and cooling expansion valves where it is metered into the evaporator coil. Then leaving the evaporator coil and passing through the suction tube of the heat exchanger, the refrigerant returns to the compressor as a low-pressure gas through the pressure regulator valve.

When discharge air is reduced to just above frosting temperature, the cooling thermostat will open and deenergize the cooling solenoid valve which cause cooling to be decreased by 75 percent as the refrigerant will be flowing through only the pumpdown expansion valve. As a result, the discharge air temperature will increase. A pressure switch is provided to maintain compressor operation in the event the

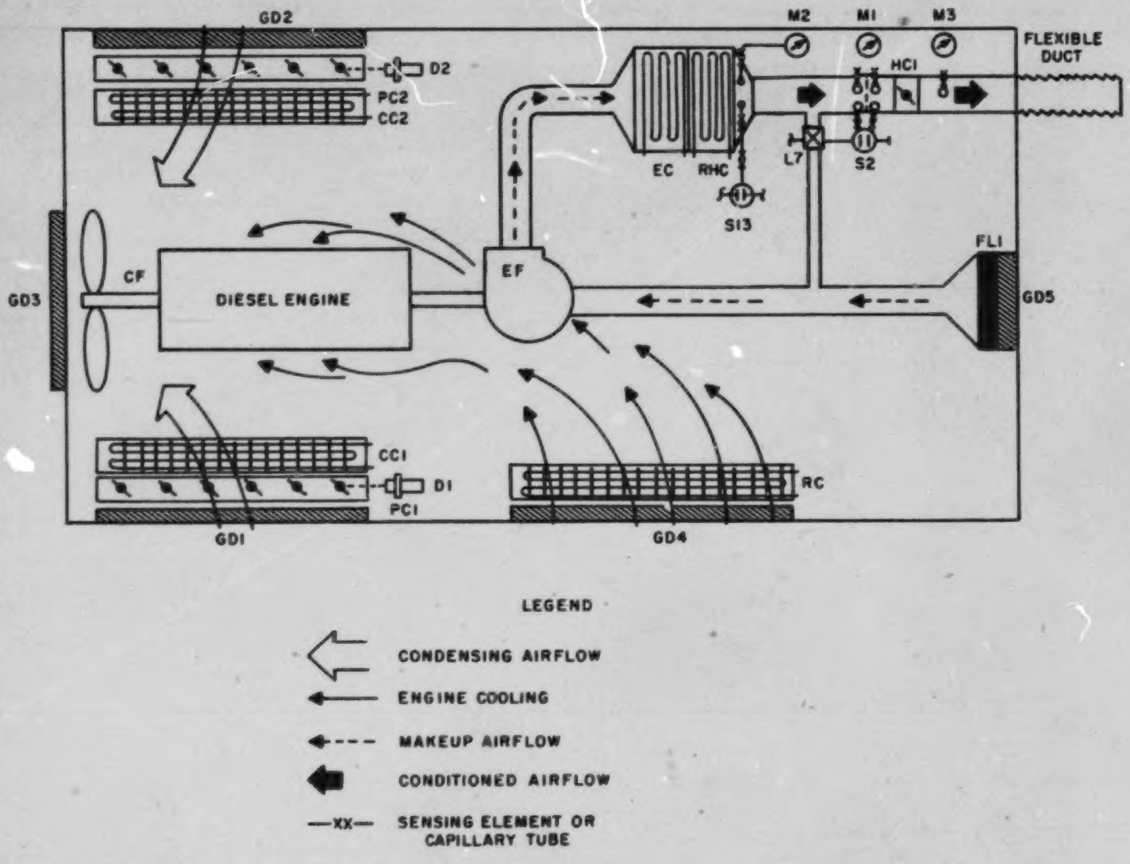

GD2
M2
M1
M3
FLEXIBLE DUCT
D2
PC2
CC2
HC1
EC
RHC
L7
S2
S13
FL1
CF
EF
GD3
DIESEL ENGINE
GD5
CC1
D1
PC1
RC
GD1
GD4
LEGEND
CONDENSING AIRFLOW
ENGINE COOLING
MAKEUP AIRFLOW
CONDITIONED AIRFLOW
—XX— SENSING ELEMENT OR CAPILLARY TUBE

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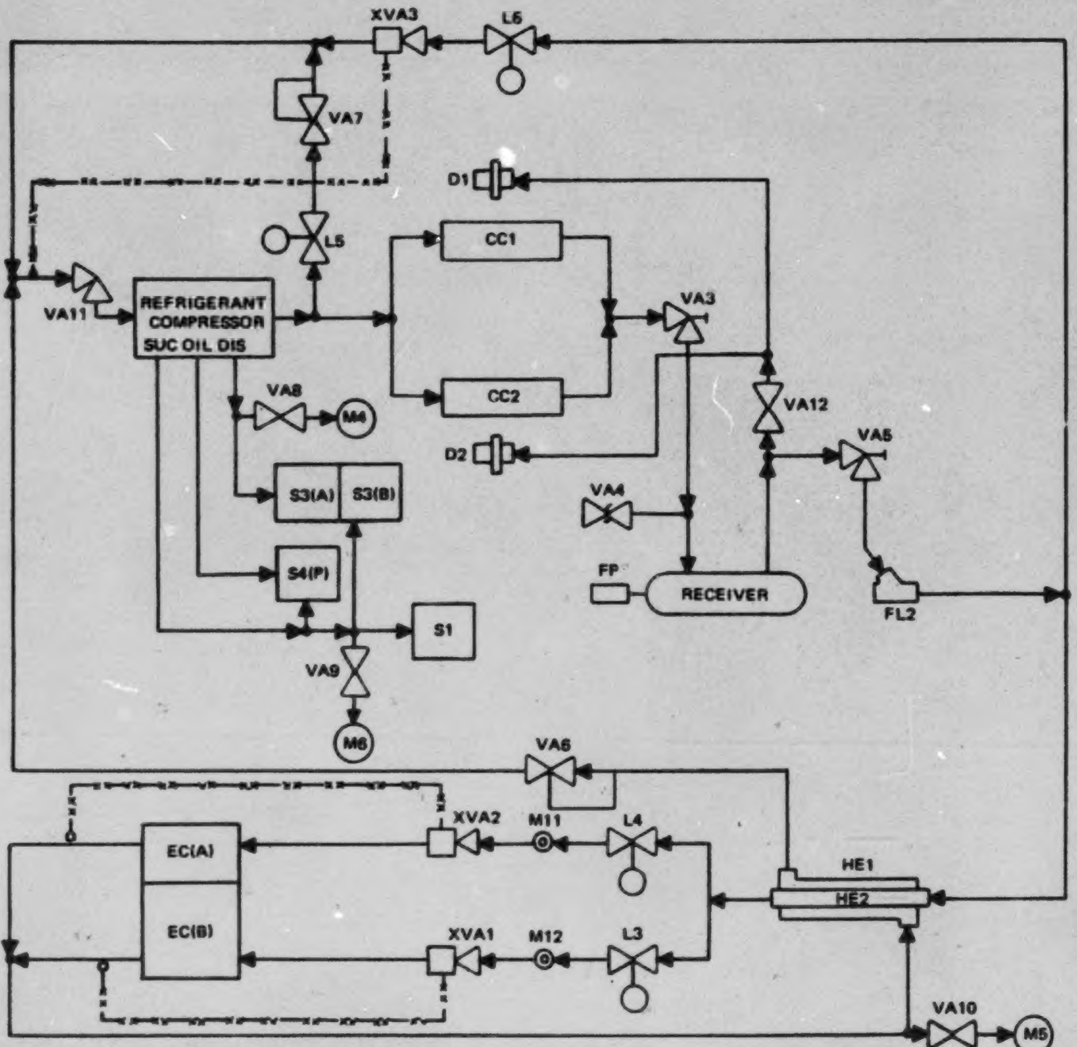
Figure 13-27.–Airflow diagram.

heat load is reduced considerably. This switch senses suction pressure and closes when suction falls below 30(±1) psig. The switch will open when the suction pressure increases to 40 (±1) psig, due to an increasing heat load.

DEHUMIDIFICATION MODE.–The dehumidification mode is initiated when the selector switch is placed in the DEHUM position. Operation of the refrigerant system is identical to that of the COOLING mode. The only change is that the water solenoid valve is energized, allowing hot engine coolant to pass through the reheat coil.

VENTILATION MODE.–The ventilation mode will be initiated after a period of time when selecting the VENT position on the control panel (fig. 13-29). This deenergizes the refrigerant system controls, with exception of the pumpdown relay and compressor clutch. With these valves closed, the refrigerant compressor will attempt to evacuate the suction side of the compressor. When the suction pressure is reduced to the set point of the low-pressure cutout switch, the high/low-pressure cutout switch opens and breaks the circuit to the pumpdown relay and the compressor clutch.


XVA3
L6
VA7
D1
L5
CC1
VA3
REFRIGERANT COMPRESSOR
SUC OIL DIS
VA11
CC2
VA12
VA8
M4
D2
VA5
S3(A)
S3(B)
VA4
FP
RECEIVER
S4(P)
FL2
S1
VA9
M6
VA6
XVA2
M11
L4
EC(A)
HE1
HE2
EC(B)
XVA1
M12
L3
VA10
M5

D1	DAMPER OPERATOR	L5	HOT GAS BYPASS SOLENOID VALVE	VA4	SAFETY VALVE
D2	DAMPER OPERATOR			VA5	CHARGING VALVE
EC	EVAPORATOR COIL	L6	QUENCH LINE SOLENOID VALVE	VA6	EVAPORATOR PRESSURE REGULATOR
FL2	FILTER - DRIER	M4	DISCHARGE PRESSURE GAGE		
FP	FUSIBLE PLUG	M5	EVAPORATOR PRESSURE GAGE	VA7	HOT GAS PRESSURE REGULATOR
CC1	CONDENSER COIL EXCHANGER	M6	SUCTION PRESSURE GAGE	VA8	SHUTOFF VALVE
CC2	CONDENSER COIL	M11	HUMIDITY INDICATOR	VA9	SHUTOFF VALVE
HE1	HEAT EXCHANGER – GAS	M12	HUMIDITY INDICATOR	VA10	SHUTOFF VALVE
HE2	HEAT EXCHANGER – LIQUID	S1	PRESSURE SWITCH	VA11	SUCTION CHARGING VALVE
L3	PUMPDOWN SOLENOID VALVE	S3(A)	HIGH PRESSURE CUTOUT	VA12	SHUTOFF VALVE
L4	COOLING SOLENOID VALVE	S3(B)	LOW PRESSURE CUTOUT	XVA1	PUMPDOWN EXPANSION VALVE
		S4(P)	OIL PRESSURE CUTOUT	XVA2	COOLING EXPANSION VALVE
		VA3	CHARGING VALVE	XVA3	QUENCH LINE EXPANSION VALVE

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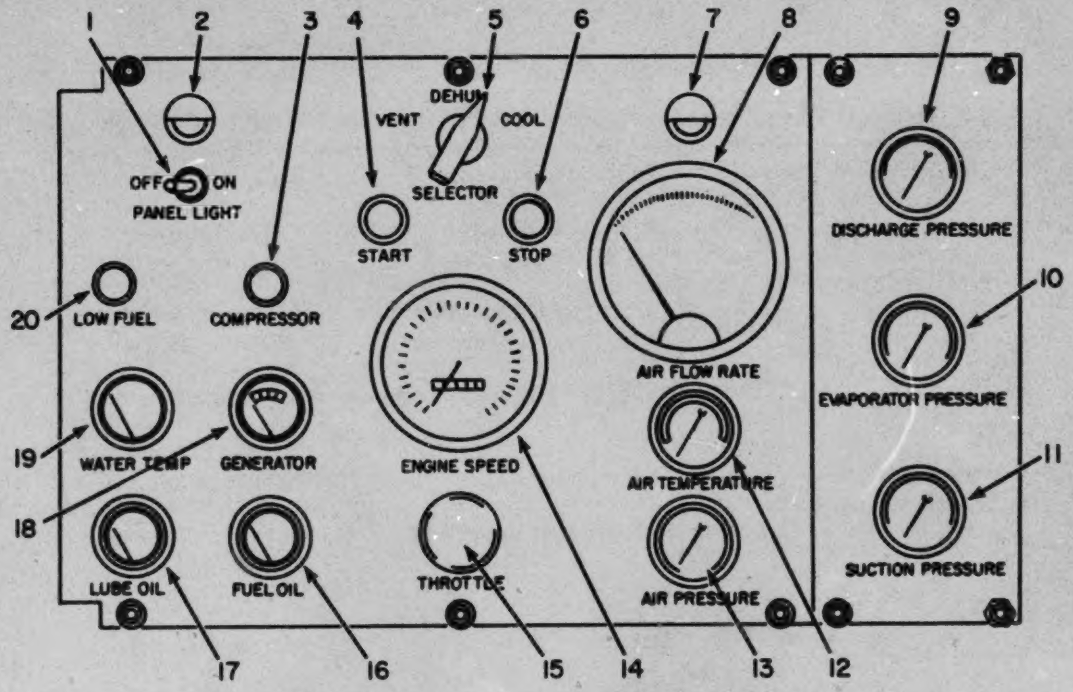
Figure 13-28.—Refrigerant flow diagram.


1
2
3
4
5
6
7
8
9
DEHUM
VENT
COOL
SELECTOR
OFF
ON
PANEL LIGHT
START
STOP
DISCHARGE PRESSURE
10
20
LOW FUEL
COMPRESSOR
AIR FLOW RATE
EVAPORATOR PRESSURE
19
WATER TEMP
GENERATOR
ENGINE SPEED
AIR TEMPERATURE
11
SUCTION PRESSURE
18
LUBE OIL
FUEL OIL
THROTTLE
AIR PRESSURE
17
16
15
14
13
12

1. Panel light switch S7
2. Panel light DS3
3. Compressor light DS2
4. Start switch S5
5. Selector switch S8
6. Stop switch S6
7. Panel light DS4
8. Airflow rate gage M1
9. Discharge pressure gage M4
10. Evaporator Pressure gage M5
11. Suction pressure gage M6
12. Air temperature gage M2
13. Air pressure gage M3
14. Engine speed indicator M13
15. Throttle control
16. Fuel oil pressure gage M8
17. Lube oil pressure gage M10
18. Battery/generator Indicator M9
19. Water temperature gage M7
20. Low fuel warning light DS1

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Figure 13-29.—Control and gage subpanels.

TROUBLESHOOTING

Not all of the possible troubles that might be encountered in conjunction with the NR-10 can be covered here; however, table 13-2 lists the troubles most likely to be encountered, probable causes for each trouble, and the remedy.

MAINTENANCE

Maintenance data for the air conditioner includes information for servicing, testing, adjusting, and lubricating. Applicable safety precautions and first aid information are also included. For more maintenance information, refer to the Operation and Service Instructions for the NR-10 air conditioner.

Servicing

Some of the more common servicing tasks are mentioned here for background information.

Table 13-2.—Troubleshooting

Trouble	Possible cause	Remedy
Panel lights fail to illuminate.	Defective lamp.	Replace lamp.
	Defective panel light switch.	Replace switch.
	Battery cables disconnected or batteries defective.	Reconnect cables or replace batteries.
	Defective wiring.	Check and repair wiring.
COMPRESSOR light fails to illuminate.	Defective lamp.	Replace lamp.
	Compressor not operating.	Refer to; Refrigerant compressor fails to start.
	Defective light.	Replace light.
	Defective wiring.	Check and repair wiring.
COMPRESSOR light illuminated; compressor not operating.	Defective light.	Replace light.
Refrigerant compressor starts with selector switch set to vent.	Defective selector switch.	Replace switch.
	Defective cooling relay.	Replace relay.
	Defective pumpdown relay.	Replace relay.
	Defective wiring.	Check and repair wiring.
Refrigerant compressor fails to start.	High/low pressure cutout switch not reset.	Press high-pressure cutout switch button.
	Oil pressure cutout switch not reset.	Press oil pressure cutout reset button.
	Suction pressure less than (±)11 psig.	Connect jumper wire across switch terminals. When compressor starts remove wire.

Table 13-2.–Troubleshooting-Continued

Trouble	Possible cause	Remedy
Refrigerant compressor fails to start. Continued	Diesel engine running too slow.	Set diesel engine to proper rpm.
	Defective high/low pressure switch.	Replace switch.
	Defective oil pressure cutout switch.	Replace switch.
	Defective diesel interlock switch.	Replace switch.
	Defective cooling relay.	Replace relay.
	Defective pumpdown relay.	Replace relay.
	Defective magnetic clutch.	Replace clutch.
	Defective refrigerant compressor.	Replace compressor.
	Defective wiring.	Check and repair wiring.
Discharge pressure gage indicates less than 168 psi.	Shutoff valve closed.	Open valve.
	Low refrigerant charge, as indicated by presence of bubbles in sight glass.	Leak test refrigerant system. If no leaks are detected, add refrigerant.
	Damper operators defective or out of adjustment.	Adjust or replace damper operators.
	Defective hot gas bypass solenoid valve.	Replace solenoid valve.
	Defective quench line solenoid valve.	Replace solenoid valve.
	Defective gage.	Replace gage.

Table 13-2.—Troubleshooting-Continued

Trouble	Possible cause	Remedy
Discharge pressure gage indicates less than 168 psi. Continued	Defective refrigerant compressor.	Replace compressor.
	Defective wiring.	Check and repair wiring.
Discharge pressure gage indicates greater than 317 psi.	Condenser coil clogged or obstructed.	Remove obstruction and clean condenser coil.
	Overcharge of refrigerant.	WARNING!!! Avoid bodily contact with liquid refrigerant. Avoid inhaling refrigerant gas. Be especially careful that refrigerant does not contact the eyes. Connect charging hose to suction charging valve, partially frontseat valve; allow small amounts of refrigerant to bleed to atmosphere until discharge pressure falls within normal operating pressure.
	Damper operators defective or out of adjustment.	Adjust or replace damper operators.
	Defective gage.	Replace gage.
Evaporator pressure gage indicates zero psi.	Shutoff valve closed.	Open valve.
	Defective gage.	Replace gage.
Evaporator pressure gage indicates less than 55 psi.	Extremely low ambient temperature (Below zero° F.)	Shut down air conditioner.
	Dirty filter or obstruction at filter guard.	Remove obstruction or service filter.
	Low refrigerant charge.	Refer to Discharge pressure problem.

Table 13-2.–Troubleshooting-Continued

Trouble	Possible cause	Remedy
Evaporator pressure gage indicates less than 55 psi. Continued	Suction pressure regulator defective or out of adjustment.	Replace or repair regulator.
	Clogged filter-drier.	Replace filter-drier core.
	Expansion valves defective or out of adjustment.	Adjust or replace expansion valves.
	Defective gage.	Replace gage.
Evaporator pressure gage indicates greater than 60 psi.	Suction pressure regulator defective or out of adjustment.	Adjust or replace regulator.
	Expansion valves defective or out of adjustment.	Adjust or replace expansion valves.
	Defective gage.	Replace gage.
Suction pressure gage indicates zero psi.	Shutoff valve closed.	Open valve.
	Defective gage.	Replace gage.
Suction pressure gage indicates less than 40 psi.	Hot gas pressure regulator defective or out of adjustment.	Adjust or replace regulator.
	Defective pressure switch.	Replace switch.
	Refrigerant compressor unloader mechanism out of adjustment.	Adjust unloaders.
	Expansion valves defective or out of adjustment.	Adjust or replace expansion valves.
	Defective gage.	Replace gage.
	Defective wiring.	Check and repair wiring.

Table 13-2.—Troubleshooting-Continued

Trouble	Possible cause	Remedy
Suction pressure gage indicates greater than 60 psi.	Refer to the above steps for the gage reading less than 40 psi.	
	Defective refrigerant compressor.	Replace compressor.
Air temperature gage indicates less than 90° F with selector switch set to DEHUM.	Extremely low ambient temperature (below 0° F).	Shut down air conditioner.
	Clogged water strainer.	Service strainer.
	Water regulator valve defective or out of adjustment.	Adjust or replace water regulator valve.
	Defective heat coil solenoid valve.	Replace solenoid valve.
	Defective cooling solenoid valve.	Replace solenoid valve.
	Defective selector switch.	Replace switch.
	Defective gage.	Replace gage.
	Defective wiring.	Check and repair wiring.
Air temperature gage indicates less than 40° F with selector set to COOL.	Extremely low ambient temperature (below 0° F).	Shut down air conditioner.
	Thermostat defective or out of adjustment.	Adjust or replace thermostat.
	Suction pressure regulator defective or out of adjustment.	Adjust or replace regulator.
	Defective cooling solenoid valve.	Replace solenoid valve.
	Defective hot gas bypass solenoid valve.	Replace solenoid valve.

Table 13-2.—Troubleshooting-Continued

Trouble	Possible cause	Remedy
Air temperature gage indicates less than 40° F with selector set to COOL. Continued	Defective quench line solenoid valve.	Replace solenoid valve.
	Defective gage.	Replace gage.
	Defective wiring.	Check and repair wiring.
Refrigerant compressor shuts down in DEHUM or COOL modes.	High discharge pressure.	Refer to trouble for discharge pressure gage indicating greater than 317 psi.
	Low suction pressure.	Refer to trouble for suction pressure gage reading less than 40 psi.
	Low compressor oil pressure.	Check oil level. If low, add oil.
	Defective selector switch.	Replace switch.
	Defective refrigerant compressor.	Replace refrigerant compressor.
	Defective wiring.	Check and repair wiring.
Refrigerant compressor fails to shut down.	Defective high/low pressure cutout switch.	Replace switch.
	Refer to trouble, refrigerant compressor starts with selector switch set to VENT.	

AIR FILTER SERVICING.—The intake air filter is of the permanent, washable type and can be cleaned as follows:

1. Remove the air filter from its mounting.
2. Inspect the filter for damage or deterioration and replace if necessary.
3. Wash the filter with dry cleaning solvent (Federal Spec. P-D-680) and flush with hot water.
4. Allow the filter to dry thoroughly and then oil lightly with general purpose lubricating oil (Federal Spec. W-L-820B or equivalent).
5. Reinstall the filter in the unit.

LEAK TESTING.—Oily film deposits around piping connections and valve bonnets are an indication of refrigerant loss. Leaks may be detected by use of a Halide torch or an electronic leak detector, as outlined below.

1. Open the access doors, remove the access panels, and remove the top of the unit to gain access to the refrigerant lines and tubes.
2. Operate the air conditioner.
3. Pass the exploring tube of a Halide torch or the probe of an electronic leak detector over all refrigerant fittings, couplings, and valves.
4. Mark all spots where leaks are found.
5. Before attempting to repair any leaks, pumpdown the refrigerant system. (Refer to the Operation and Service Instructions for pump-down procedure.)
6. Repair all leaks detected.
7. Refer to the Operation and Service Instructions for procedures for pressure testing and dehydrating the system.

DRIER-STRAINER (DEHYDRATOR) SERVICING.–Replace the drier-strainer cartridge as follows:

1. Refer to the Operation and Service Instructions and pumpdown the system.
2. Remove the six bolts securing the cap on the drier case, and remove the cap.
3. Remove the cartridge from the case and install a new cartridge.
4. Replace the case cap.
5. Refer to the Operation and Service Instructions and evacuate and dehydrate the system.
6. Leak-test the drier-strainer at the cap as previously described.

First Aid Treatment

If liquid refrigerant comes into contact with the skin, a serious injury will result. Such injury must be treated as if the skin were severely frostbitten or frozen. Flush the area with clean water and seek medical attention immediately. If liquid refrigerant comes into contact with the eyes, flush with clean water and, again, seek medical attention immediately.

Safety Precautions

The precautions presented here must be observed in order to prevent injury to personnel working on or in the immediate vicinity of any air-conditioning unit while maintenance is being performed on the unit.

1. Suitable eye protection must be used when handling refrigerants.
2. Never heat a refrigerant drum with a torch or any other open flame.
3. When repairing a refrigerant system, always blow out any residual refrigerant before attempting to heat the pipe or tubing.
4. Never put liquid refrigerant into a compressor suction line.
5. Inspect all charging lines for brittleness and condition of the couplings prior to use.
6. Do not allow refrigerant to come into contact with the skin.
7. If a large refrigerant spill occurs, ventilate the space immediately.

CHAPTER 14

PRESERVATION

Suitable protection against corrosive attack is achieved essentially by placing a barrier between the cleaned surface that is to be protected and any possible source of moisture. During manufacture or overhaul, protective barriers such as electroplate, paint, or chemical surface treatment are provided. Surfaces that cannot be so treated, and in some instances the treated surfaces themselves, must be covered with special corrosion-preventive compounds.

PRESERVATION METHODS

The protection given by corrosion-preventive compounds is effective only if no moisture, dirt, or active corrosion is present on the treated surface. It is essential, therefore, that the equipment be thoroughly clean and dry before a preservative compound is applied. It is also necessary that an unbroken film of preservatives be applied in an atmosphere as moisture free as practicable.

Compounds alone do not provide complete protection. Tapes, barrier paper, and sealing devices must also be used to seal off openings which, if allowed to remain open during long-time stowage, would permit the entry of moisture and dirt. To provide additional protection against corrosion, a complete moisture barrier is sometimes provided. Internal areas that have been sealed off are dehydrated by installing desiccants (moisture absorbents) to remove entrapped moisture unless the cavity is protected with a vapor corrosion inhibitor. When any areas cannot be sealed adequately, provision must be made for ventilation and moisture drainage.

When certain ground support equipment is not being used regularly, its components are required to be preserved. The type of oil or other protective treatment which is to be applied subsequently depends upon the anticipated period of idleness.

The following paragraphs contain a summary of the different classifications of preservation which have been adopted as standard and the applications for which each is intended. The ASM should be familiar with these classifications or types. These types are for uninstalled gas turbine engines and the engines that are scheduled for early removal from equipment. Refer to NAVAIR 15-02-500 or to the proper equipment manual for correct procedures.

Type I preservation of gas turbine engines includes internal protection of the various fluid systems under type II or type IV requirements, followed by installation of the engines in dehydrated containers.

Type II preservation of gas turbine engines accomplishes the protection of all fluid systems, followed by sealing of external openings to prevent the entrance of foreign materials and moisture. Gas turbine engines in type II nondehydrated status require rotation with the starter or an external turning device at least once every 30 days.

Type III preservation differs from type II in that the entire engine fuel system, including all lines, pumps, and metering devices, is kept filled with the specified service fuel. Also for type III preservation, the sealing of external openings may be more casual; openings may be closed by the dust excluders or plugs.

Type IV preservation for inoperable gas turbine engines differs from types II and III in that a powered (hot) engine run is not required. Instead, exercising the engine, rotating components, and redistribution of the lubricating oil to the bearings may be accomplished by rotating the engine with the starter or an external turning device. Type IV preservation is designed for the protection of engines inoperable due to missing parts or accessories, lack of test stand facilities, or internal failure.

Type V preservation includes the emergency treatment of gas turbine engines in which the engine has been exposed to salt water, foamite, or other firefighting chemicals.

In maintenance of metal surfaces, preservation means supplementing the protection already present, or providing temporary protection to damaged areas, by the use of various protective coatings and barrier materials. A brief description of some of the more common materials used in preservation is included in the following paragraphs.

SOLVENT CUTBACK COMPOUND

This material is familiarly known as "paralketon." It is supplied in four grades for specific application. All grades of this compound may be applied by brush, dip, or spray. They may be easily removed with Stoddard Solvent or mineral spirits. These materials are designed for cold application. Some preservative compounds must be applied hot; therefore, when intending to use one of the grades of this solvent cutback material, the specification number (MIL-C-16173) should always be verified.

Grade 1 forms a dark, hard-film, opaque cover. Its general use is limited because of the difficulty in removing aged coatings and also because of the hiding power of the material when it is applied over corroded areas. This material is used only where maximum protection against salt spray is required.

Grade 2 is a soft-film, grease-type material that can be used on most operating parts. Its chief disadvantage is the fact that it may be washed off under direct exposure to salt water or may be removed by inadvertent wiping. It protects under relatively severe conditions and, given adequate maintenance and touchup as necessary, can be used for most maximum protection requirements.

Grade 3 is a very light, water-displacing preservative, with the ability of penetrating under surface water and forming a protective film on the metal. This material is most effective in treatment of equipment or components after direct exposure of critical surfaces to water of firefighting chemicals, or for internal protection of water-carrying systems. This grade itself offers only limited protection for short periods of time and must be supplemented by frequent maintenance or heavier materials as soon as practicable.

Grade 4 preservative forms thin, semitransparent films through which identification data can usually be read. It also sets up relatively dry to the touch so that preserved parts may be easily handled. This grade has proved particularly effective in protecting wheel well areas and other exposed surfaces where film transparency is required and moderate protective characteristics can be tolerated. The main disadvantages of this material are that it is easily removed by water spray and requires replacement at 1-month intervals under severe exposure conditions.

CORROSION-PREVENTIVE PETROLEUM

These preservatives are designed for hot application and are available in two classes—Class 1 (hard film) and Class 3 (soft film). Both consist of corrosion inhibitors in petroleum. They are removed with Stoddard Solvent or mineral spirits. Where a hard film is not necessary, Class 3 should always be used as it is easier to apply and remove yet renders the same degree of protection. Class 1 is generally used for longtime indoor protection of highly finished metal surfaces. Class 3 is used to provide protection of metal surfaces such as antifriction bearings, pistons, and other bright metal surfaces.

Class 1 must be heated to 170° to 200° F before applying by brush or dip. For brushing

Class 3 material, it must be between 60° and 120° F, and for dipping, between 150° and 180°F.

PACKAGING AND BARRIER MATERIALS

Packaging and barrier materials are used to seal off critical areas of support equipment during shipment, storage, maintenance, and repair. These materials are also used to protect removed components when they are sent to overhaul.

Water-Vaporproof Barrier Material

This material is a laminated metal foil barrier that has good water-vapor resistance and can be used for protection of acrylics during cleaning, and for necessary packaging of removed components and accessories being returned to overhaul. It is heat-sealable with a soldering or clothes iron.

Polyethylene Plastic Film

This barrier material is used for the same purposes as the metal foil barrier material and is much less expensive. It is, however, not puncture resistant. The plastic film is heat sealable only with special equipment.

Polyethylene Coated Cloth

Cloth of this type is used to a greater extent in ground support equipment covers. Its use is preferred over the plastic material for general shrouding because of its greater tear and puncture resistance.

Tape, Federal Specification PPP-T-60, TYPE I, CLASS 1

This pressure-sensitive tape is used for closure of small openings and for direct contact use on noncritical metallic surfaces. The tape has moderate water-vapor resistance, which is generally adequate for maintenance use. The main disadvantage of this tape is that some cloth-backed materials have not been preshrunk, and tape closures tend to pull loose when exposed to high humidity conditions.

Covers and Shrouds

Many types of support equipment, when delivered by the manufacturer, are equipped with a complete set of tailored dust and protective covers. These covers and shrouds should be installed in such a manner that free drainage is assured. Do not create a bathtub which will trap and hold water. Shrouds or covers may also act as a greenhouse in warm weather and cause collection and condensation of moisture underneath. The shroud should be loosened or removed and the equipment ventilated on warm sunny days. Where protection from salt spray is required aboard carriers, the covers should be left in place and the equipment ventilated only in good weather. Fresh water condensation will do far less damage than the entrapped salt spray.

In emergencies where regular waterproof canvas covers are not available, suitable covering and shrouding may be accomplished by using polyethylene sheet, polyethylene-coated cloth, or metal foil barrier material, all of which are available in the Navy supply system. These covers should be held in place with adhesive tapes designed specifically for severe outdoor application. The tapes are also available in supply.

GENERAL HANDLING

There are many commonsense practices which should be observed to minimize paint damage and the loss of built-in protective systems during operation and maintenance of support equipment.

Painted surfaces will withstand a normal amount of abrasion by air lines, fuel hoses, etc. However, these items pick up bits of sand, gravel, and metal chips and become a coarse abrasive which scratches and scruffs the protective finish to the point where it is rendered completely ineffective under shipboard operating conditions. Dropping tools, toolboxes, etc., on the surface also chips and cracks the paint.

When access plates are removed during inspections, the removed hardware should not be placed on the deck to blow around and become scratched. It is not practical to provide pads or cushioning for these components, but they should at least be secured to prevent their movement. When power tools or handtools are used to remove screws and quick-disconnect fasteners, particular care should be taken to avoid scratching the paint. Five minutes of extra time spent in careful use of tools will save 5 hours of paint touchup and corrosion removal work later.

PAINTING

The ASM will be required to involve himself in extensive painting projects, although the ASH has the basic responsibility for painting. However, he may be called upon to aid in the preparation of the surfaces to be painted and may even perform small painting jobs where a paint touchup is all that is necessary as part of a corrosion-prevention program. Therefore, painting is discussed very briefly and is pointed toward paint touchup.

Surface Preparation

Effectiveness of any paint finish and its adherence to the surface depends on the careful preparation of the surface prior to painting. First, all loose paint must be brushed off, and curled or flaky edges must be removed if good adhesion is to be attained. The touchup paint should overlap the existing good paint surface. The touchup materials will not adhere to glossy finishes, and the rough edge of the area being painted may chip away unless it is smoothed. To break the glossy finish and to feather (smooth out) the edges for overlap, scuff-sand with abrasive paper of the appropriate type, depending upon the type of surface being repaired. This paper should be a fine abrasive material, or a pumice slurry in water may be used in its place. The sanded pattern should provide about a one-half-inch overlap for the new paint. After the abrasive operation is completed, wash the area with fresh water to remove all abrasive residues.

Next, all sanded areas and exposed bare-metal surfaces are wiped down with light mineral spirits solvent or alcohol, followed by a washing with detergent. Remove any loosened seam sealants in the area to be touched up and replace as necessary; this includes securing any loose rubber seals. The area to be painted is then outlined with masking tape and masked with a masking paper to protect adjoining surface areas from overspray and excessive paint buildup.

DEPRESERVATION

The support equipment under the care of the ASM may be depreserved to be put into service or rework, or for inspection and represervation for another storage period. This will determine the extent of the depreservation. Regardless of status of equipment, depreservation must always include the removal of deteriorated lubricants, preservative coatings, barrier materials, strippable plastic coatings, and tapes. If equipment is being depreserved for represervation for another storage period, a decision must be made to either remove and replace the plastic coating or leave the coating in place and touch it up or topcoat it with topcoating material until complete coverage is obtained. Coatings must be removed as necessary to expose engine and other systems for inspection and represervation. If the equipment is to be put into service, all preservative must be removed.

Depreservation of gas turbines will comply with NAVAIR 15-02-500, Preservation of Aircraft Engines. The depreservation of a gas turbine consists of the following: removal of all protective coverings and seals; drainage of excess preservative compounds from the fuel and oil systems; and servicing of the fuel and oil reservoirs to normal operating levels with the specified operating materials.

After servicing the fuel and oil systems, the engine should be run for about 10 minutes with no load. After this short run time, the lube oil must be changed and the fuel and oil filters inspected and cleaned or replaced if necessary.

Equipment properly preserved and maintained should require a minimum of cleaning after the storage period. Most of the cleaning should be accomplished during the removal of preservatives, tapes, and barrier materials. Cleaning should be accomplished on the basis of inspection, evaluation, and equipment status. The use of steam and high-pressure water cleaning should be avoided when the equipment is to be returned to storage. Hand-cleaning methods should be used, including vacuum cleaners to remove dust and dirt and hand wipedown methods to remove oils, greases, and preservatives. Cleaning should be complete enough to remove the preservative and yet utilize the mildest procedures and materials that will do the job. Plastic coatings and tapes can be removed by stripping from the equipment. Adhesive residues from pressure tape may be removed by rubbing with a cloth saturated with aliphatic naphtha.

Equipment being depreserved after ocean shipment must be given special attention to ensure removal of entrapped sea water and salt deposits as soon as possible. Equipment protected by strippable plastic coatings should be checked soon after arrival for water pockets by punching holes at low points in any bulges or sags in the coating. Equipment not plastic-coated should be examined for accumulations of sea water. Sea water deposits must be removed immediately by flushing with fresh water even though the equipment is to be depreserved in the near future.

Lubrication is an essential part of depreservation since application of lubricants to clean metal surfaces provides protection against the harmful effects of dirt, water, and other agents. Following cleaning or stripping of equipment, lubricate all exposed points and any points that have been exposed to cleaning and stripping compounds. All grease fittings should be greased to force dirt, water, and other harmful agents from moving parts. The equipment maintenance manual should be consulted for lubrication procedures. Following depreservation and before placing the equipment in service, thoroughly inspect the equipment for corrosion damage and correct any found.

Some of the preservants used on equipment and the method of removal are listed in table 14-1.

CORROSION CONTROL

Modern ground support equipment is dependent upon the structural soundness of the metals which make up the largest percentage of their thousands of parts. The greatest threat to the structural integrity of the equipment is metals corrosion. With higher strength demands

Table 14-1.–Equipment preservants

Preservant	Method of Removal
Plastic protective coating	Manually strippable.
Soft film compound.	By drycleaning solvent P-D-680 or mineral spirits TT-T-291.
Corrosion preventive fingerprint remover.	Rinse with drycleaning solvent P-D-680 or mineral spirits TT-T-291
General purpose lubricating oil.	By drycleaning solvent P-D-680 or mineral spirits TT-T-291.
Packaging materials.	Remove overwrap or liner.

being made of metals and the closer tolerances of safety demanded, these equipments would rapidly become inoperative without regular anticorrosion attention.

Corrosion endangers support equipment by reducing the strength and changing the mechanical characteristics of the materials used in its construction. Materials are designed to carry certain loads and withstand given stresses as well as to provide an extra margin of strength for safety. Corrosion can weaken the structure, thereby reducing or eliminating the safety factor. Replacement or reinforcement operations are costly and time consuming, and reduce usage. Corrosion in electronic, electrical, and automotive systems often causes serious malfunctions which reduce the effectiveness of the equipment, and often destroys it completely.

Material presented in this chapter has been compiled from a variety of sources and has necessarily been greatly condensed. As with other training courses, no maintenance procedures should be initiated which are based solely on information contained herein.

A thorough comprehension of the dangers of corrosion, the ability to recognize the various types of corrosion, and the development of the skills necessary to cope with them should be included in the objectives as every maintenance training program. The ASM will find that corrosion control frequently turns out to be an all-hands evolution. In his day-to-day work he can improve the quality of corrosion control by observing precautions outlined herein when working on ground support equipment. Careless handling of tools and equipment, scuffing of feet, etc., can result in damage to protective finishes leaving an area unprotected from corrosion. Even a fingerprint on an unprotected surface will cause corrosion and etching of the metal.

Metal corrosion is the deterioration of metal when combined with oxygen to form metallic oxides. This combining is a chemical process which is essentially the reverse of the process of smelting the metals from their ores. Very few metals occur in nature in the pure state. For the most part, they occur naturally as metallic oxides. The refining processes generally involve the extraction of relatively pure metal from its ore and the addition of other elements (either metallic or nonmetallic) to form alloys.

After refining, regardless of whether or not alloyed, base metals possess a potential or tendency to return to their natural state. However, the potential is not sufficient in itself to initiate and promote this reversion. There must also exist a corrosive environment, in which the significant element is oxygen. It is the process of oxidation—combining with oxygen—that causes wood to rot or burn and metals to corrode.

Control of corrosion is dependent upon maintaining a separation between susceptible alloys and the corrosive environment. This separation is accomplished in various ways. An intact coat of paint provides corrosion protection. Sealants are used at seams and joints to prevent entry of moisture into vital areas, preservatives are used on unpainted areas of working parts, and shrouds, covers, caps, and other protective material provide varying degrees of protection from corrosive action. None of these, however, provide 100-percent protection—paint is subject to oxidation and decay through weathering; sealants may work out by vibration or else be eroded by rain and windblast. Preservatives at best offer only temporary protection when used on operating support equipment, and the protective coverings are subject to improper installation and neglect.

CAUSES OF CORROSION

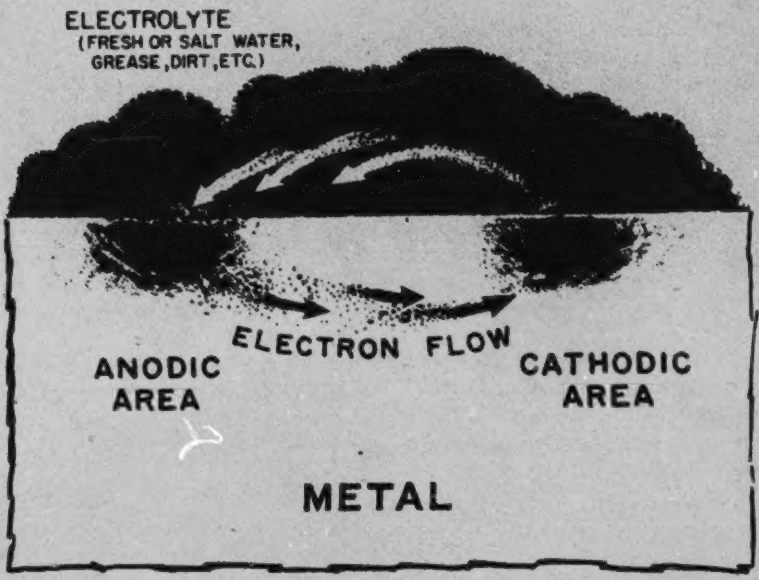
Control of corrosion properly begins with an understanding of the causes and nature of this phenomenon. Corrosion is caused by electrochemical or direct chemical reaction of a metal with other elements. In the direct chemical attack, the reaction is similar to that which occurs when acid is applied to bare metal. Corrosion in its most familiar form is a reaction between metal and water and is electrochemical in nature.

In the electrochemical attack, metals of different electrical potential are involved and they need not be in direct contact. When one metal contains positively charged ions and the other negatively charged ions and an electrical conductor is bridged between them, current will flow as in the discharge of a dry cell battery. In electrochemical corrosion, the conductor bridge may be any foreign material such as water, dirt, grease, or any debris that is capable of acting as an electrolyte. The presence of salt in any of the foregoing media tends to accelerate the current flow and hence speed the rate of corrosive attack.

Once the electrolyte has completed the circuit, the electron flow is established within the metal in the direction of the negatively charged area (cathode), and the positively charged area (anode) is eventually destroyed. All preventive measures taken with respect to corrosion control are designed primarily to avoid the establishment of the electrical circuit, or secondly, to remove it as soon as possible after establishment before serious damage can result. Figure 14-1 illustrates the electron flow in a corrosion environment (electrolyte), resulting in destruction of the anodic area. Note that the surface of a metal, especially alloys of the metal, may contain anodic and cathodic areas due to impurities or alloying constituents which have different potentials from the base metal.

Electrochemical attack is evidenced in several forms, depending upon the metal involved, its size and shape, its specific function, atmospheric conditions, and the type of corrosion-producing agent (electrolyte) present. There are many forms of metals deterioration resulting from electrochemical attack about which a great deal is known. But despite extensive research and experimentation, there is still much to be learned about other more complex and subtle forms. Descriptions are provided later in this chapter for the more common forms of corrosion.

Since there are so many factors which contribute to the process of corrosion, selection of materials by the manufacturer must be made with weight versus strength as a primary consideration and corrosion properties as a secondary consideration. However, close attention during design and production is given to heat-treating and annealing procedures, protective coatings, choice and application of moisture barrier materials, dissimilar metals contact, and access doors and plates. Every



213.49

Figure 14-1.–Simplified corrosion cell.

logical precaution is taken by the manufacturers to inhibit the onset and spread of corrosive attack.

There are many factors that affect the type, speed, cause, and the seriousness of metal corrosion. Some of these corrosion factors can be controlled; others cannot. Preventive maintenance factors such as inspection, cleaning, and painting and preservation are within the control of maintenance personnel. Preventive maintenance offers the most positive means of corrosion deterrence.

The electrochemical reaction which causes metal to corrode is a much more serious factor under wet, humid conditions. The salt in sea water and in the air is the greatest single cause of corrosion. Hot climates speed the corrosion process because the electrochemical reaction develops fastest in a warm solution, and warm moisture in the air is usually sufficient to start corrosion if the metals are uncoated. As would be expected, hot dry climates usually provide relief from constant corrosion problems. Extremely colt climates produce corrosion problems if a salt atmosphere is present. Melting snow or ice provides the necessary water to begin the electrochemical reaction.

Another corrosion factor is in the relationship between dissimilar metals. When two dissimilar metals are used where possible contact may develop (if the more active metal is small, compared to the less active one), corrosive attack will be severe and extensive if the insulation should fail. If the area of the less active metal is small compared to the other, anodic attack is relatively slight. Figure 14-2 illustrates this factor.

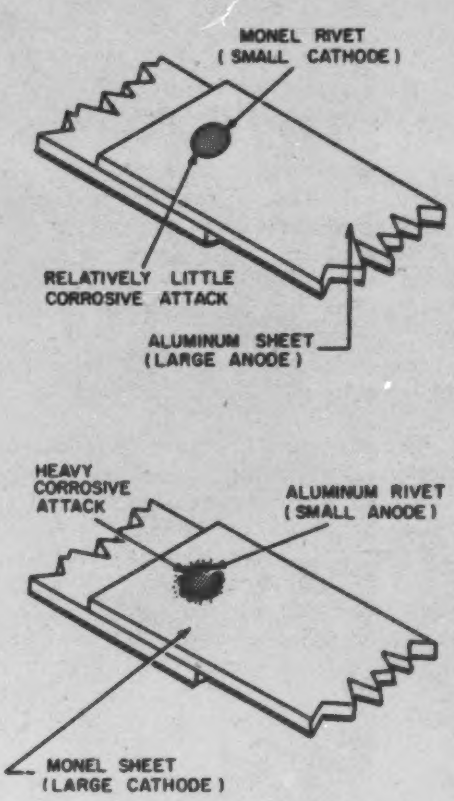


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Figure 14-2.—Effects of area relationships in dissimilar metal contacts.

CORROSION TYPES AND RECOGNITION

One of the problems involved in corrosion control is recognizing corrosion products when they occur. The following paragraphs include brief descriptions of typical corrosion product characteristics of the most common metals.

Iron and Steel

Possibly the best known and easiest recognized of all forms of metal corrosion is the familiar reddish colored iron rust. When iron and its alloys corrode, dark iron oxide coatings usually form first. These coatings, such as heat scale on steel sheet stock, may protect iron surfaces rather efficiently. However, if sufficient oxygen and moisture are present, the iron oxide is soon converted to hydrated ferric oxide, which is the conventional red rust.

Aluminum

Aluminum and its alloys exhibit a wide range of corrosive attack, varying from general etching of aluminum surfaces to penetrating attacks along the internal grain boundaries of the metal. The corrosion products of aluminum are seen as white to gray powdery deposits.

Magnesium and Its Alloys

Magnesium corrosion products are white and quite large compared to the size of the base metal being corroded. The deposits have a tendency to raise slightly, and the corrosion spreads rapidly. When white puffy areas are discovered on magnesium, it requires prompt attention as the corrosion may penetrate entirely through the structure in a very short time.

Copper and Copper Alloys

Copper and its alloys are generally corrosion-resistant, although the products of corrosive attack on copper are commonly known. Sometimes copper and copper alloy surfaces will tarnish to a dull gray-green color, and the surface may still be relatively smooth. This discoloration is the result of the formation of a fine-grained, airtight, copper oxide crust, called a patina. This patina in itself offers good protection for the underlying metal in ordinary situations. However, exposure of copper and copper alloys to moisture or salt spray will cause the formation of blue or green salts indicating active corrosion. These salts will form over the patina since this crust is not impervious to water (not moistureproof). Copper alloys generally have a cadmium-plated finish to prevent surface staining and deterioration.

Cadmium and Zinc

Cadmium, particularly, is used as a coating to protect the part to which it is applied and to provide a compatible surface when the part is in contact with other materials. The cadmium plate supplies sacrificial protection to the underlying metal because of its greater activity; that is, during the time it is protecting the base metal, the cadmium is intentionally being consumed. The cadmium becomes anodic and is attacked first, leaving the base metal free of corrosion. Zinc coatings are used for the same purpose, but to a lesser extent. Attack is evident by white to brown to black mottling of the cadmium surfaces. These phenomena DO NOT indicate deterioration of the base metal. Until the characteristic colors peculiar to corrosion of the base metal appear, the cadmium is still performing its protective function. Wire brushing or removal of the mottled areas of cadmium merely reduces the amount of cadmium remaining to protect the underlying structure.

Nickel and Chromium Alloys

These metals are also used as protective agents, both in the form of electroplated coatings and as alloying constituents with iron in stainless steels. Nickel and chromium plate protect by forming an actual physical noncorrosive barrier over the steel. Electroplated coatings, particularly chromium on steel, are somewhat porous, and corrosion eventually starts at these pores or pinholes unless a supplementary coating is applied and maintained.

CORROSION PREVENTION

Among the many methods of corrosion prevention, cleaning and lubrication are two very important measures to consider in the prevention of corrosion in ground support equipment. Methods of cleaning and lubrication of specific equipment are included in the chapters discussing the particular equipments. This section discusses the various Naval Air Systems Command authorized cleaning and lubricating materials available to the ASM.

Cleaning and Depreservation

Cleaning is one of the most important steps in the preparation of unpainted surfaces for stowage or for the application of protective coatings. Cleaning is also important in reconditioning contaminated and deteriorated surfaces prior to lubrication. If contaminants remain on the surfaces of equipment, the best lubricants or preservatives and the best methods of protection and preservation for standby stowage may be rendered ineffective. Corrosion and contamination may cause faulty operation of the equipment or deterioration beyond reclamation.

The removal of preservative coatings is sometimes necessary before items in storage can be used. Therefore, an additional task in which cleaning methods are important is depreservation.

Only cleaning materials which meet Naval Air Systems Command specifications may be used on ground support equipment. Navy-approved cleaning materials are compounded to accomplish definite results and are made available only after complete testing and actual field acceptance. All cleaning materials are inspected and tested before acceptance and delivery to the supply activities. Cleaning agents commonly used for maintenance cleaning are included in the following categories.

SOLVENTS.–Solvents are liquids which dissolve other substances. There are a great number of different solvents; but for cleaning purposes, organic solvents are most often used. Some solvents are chlorinated. When solvents contain more than 24 percent by volume of chlorinated materials, they must be kept in specially marked containers. Care must be taken to ensure that solvents do not escape into the work spaces.

All personnel working with or near chlorinated solvents should be particularly careful to avoid breathing the vapors. While the vapors from some solvents are more toxic than others, prolonged breathing of the fumes can be injurious to health.

In addition to the breathing hazard associated with solvents, they also present varying degrees of fire and explosion hazards. Solvent cleaners having a flashpoint greater than 105° are relatively safe. Solvents having flashpoints below 105° F require explosion proofing of equipment and other special precautions. (The flashpoint is the temperature at which the first flash from the material is seen, as an open flame is passed back and forth over a sample of flammable liquid being heated in a cup.)

Another hazard associated with solvents, and to a certain extent with all cleaning materials, is the effect on the surface or material being cleaned. Some solvents will deteriorate rubber, synthetic rubber, asphaltic coverings, etc. This is such an important consideration that it must always be taken into account when cleaning materials are selected. It may do a good job in removing dirt, grease, oil, exhaust gas deposits, etc., but may also damage the object being cleaned or soften and ruin otherwise good paint coatings.

Several solvents in common use are included in the following list:

1. Stoddard Solvent. Stoddard Solvent is a petroleum distillate commonly used as a dry-cleaning fluid. It is furnished in two types–I and II. Type II has the higher (safer) flashpoint and is intended for shipboard use. Stoddard Solvent is used as a general all-purpose cleaner for metals, painted surfaces, and fabrics. It may be applied by spraying, brushing, dipping, and wiping. It is also used as a depreservative.

2. Mineral spirits. This is another liquid petroleum distillate which is used as an all-purpose cleaner for metal and painted surfaces, but is not recommended for fabrics. Like Stoddard Solvent, it may be applied by spraying, brushing, dipping, and wiping.

3. Aliphatic naphtha. This is an aliphatic hydrocarbon product used as an alternate compound for cleaning acrylics and for general purposes that require fast evaporation and no remaining film residue. It may be applied by dipping and wiping. Saturated surfaces must not be rubbed vigorously due to the highly flammable nature of the naphtha.

4. Acromatic naphtha. This is a petroleum aromatic distillate used as a bare-metal cleaner and for cleaning primer coats before applying lacquer. It will remove oil, grease, and light soils.

5. Safety Solvent. Methyl chloroform is intended for use where a high flashpoint and the least toxic solvent is required. It is used for general cleaning and grease removal of assembled and disassembled components in addition to spot cleaning, but should not be used on painted surfaces. It may also be applied by wiping, scrubbing, or booth spraying. The term Safety Solvent is derived from the high flashpoint of the solvent and is easier to say and remember than methyl chloroform.

6. Corrosion preventive, fingerprint remover, MIL-C-15074B. This compound is

intended for use in removal of fresh fingerprints and perspiration deposits. It is designed to suppress corrosion that has developed as a result of fingerprint residue, and provides an easily removable temporary corrosion-preventive material.

7. Thinner, cellulose nitrate dope and laquer. In addition to its intended purpose of thinning dope and lacquer, this material is used for the spot removal of lacquer and primer deposits remaining after paint stripping operations, especially along seams and edges, which will interfere with refinish paint operations. Also, it may be used for removal of oil, grease, and light soils from bare metal. This solvent is applied with wiping rags or soft bristle brushes over small areas at a time.

8. Methyl ethyl ketone (MEK). This material is used as a cleaner for bare-metal surfaces. It does not mix to any great extent with water but is a thinner for lacquers. It is applied with wiping cloths or soft bristle brushes over small areas at a time.

EMULSION CLEANERS.–Emulsion cleaners differ from solvent cleaners in their action on contaminants to be removed. With solvents, the contaminants go into solution with the cleaning material. Emulsion cleaners tend to disperse contaminants except sand, etc., into tiny droplets which are held in suspension in the cleaner.

Emulsion cleaners must be used with precaution since some are flammable and toxic and, like some solvents, may damage paint or other finishes.

The following list includes several cleaners in common use:

1. Cleaning compound, solvent, grease emulsifying, type I. This is a liquid emulsifying agent containing soap and solvent. It is nonphenolic. (See type II which follows.) This compound is used for exterior cleaning, all painted surfaces (metal and wood), and bare metal. It is a heavy-duty cleaner for removal of oil, grease, atmospheric films, industrial films, mud, sand, and soils. of all types. It is also used for removal of paralketones and similar corrosion-preventive compounds (preservatives).

Both types (I and II) of this compound must be mixed with Stoddard Solvent or mineral spirits prior to use. A ratio of 1 part compound to 3 to 9 parts of solvent is recommended. Heavy soils require the heavier concentration. The heavy concentrations clean best when the ambient temperature is high.

For best results this compound should be sprayed on the dry surface then brushed thoroughly. Moist or water-wetted surfaces reduce the emulsion action. It can be used for hand wipedown or hand scrubbing on small areas. Regardless of the method of application, the emulsion compound and loosened soil should be thoroughly flushed away with high-pressure water.

2. Cleaning compound, solvent, grease emulsifying, type II. This is a liquid emulsifying compound containing phenolic materials. (Phenolic materials are obtained from the distillation of many organic substances such as wood, coal, etc., and from coal tar. The popular name for the phenols is carbolic acid.) Due to the acid content and type of cleaning for which designed, its use is very limited. Type II cleaning compound is designed for the heaviest, toughest cleaning jobs, but its acidity renders it harmful to many materials.

3. Cleaning compound, water emulsion. This is a liquid emulsifying agent containing soap and water and is used in solution with four parts water for the heavy-duty removal of oil, epoxy, grease, industrial films, mud, sand, and soils of all types. This material is applied with a brush or soft cloth. Allow it to remain on the surface, then scrub with a soft brush. Rinse the surface thoroughly with fresh water, and dry. Repeat for areas with heavy concentrations by using a scouring pad.

SOAPS AND DETERGENT CLEANERS.–There is a variety of materials available in this category for mild cleaning use. In this section, only some of the more common materials are discussed.

1. Cleaning compound, type I (powder) and type II (liquid). These soaps are used in general cleaning of painted and unpainted surfaces for the removal of light-to-medium soils, operational films, oils, and grease. They

are safe to use on all surfaces, including fabrics, leather, and transparent plastics. They also can be used to remove light preservation materials.

2. Cleaning compound, waterless. This cleaning compound is intended for use on painted and unpainted surfaces in heavy-duty cleaning operations under conditions where water for rinsing is not readily available or where freezing temperatures do not permit the use of water. It is a relatively nontoxic, noncorrosive, stable, nonflowing gel, and its detergent properties enable it to serve as an agent for the removal of grease, tar, wax, carbon deposits, and exhaust stains. This cleaner is applied with a dampened cloth or sponge except in freezing weather when a dry applicator should be used.

MECHANICAL CLEANING MATERIALS.–Mechanical cleaning materials such as abrasive papers, polishing compounds, polishing cloths, wools, wadding, etc., are available in the supply system for use as needed. However, their use must be in accordance with directions supplied with the material if damage to finishes and surfaces is to be avoided.

1. Aluminum oxide paper. Aluminum oxide paper (300 grit or finer) is available in several forms and is safe to use on most surfaces since it does not contain sharp or needlelike abrasives which can embed themselves in the base metal being cleaned or in the protective coating being maintained. The use of carborundum (silicon carbine) papers as a substitute for aluminum oxide paper should be avoided. The grain structure of carborundum is sharp, and the material is so hard that individual grains can penetrate and bury themselves even in steel surfaces.

2. Powdered pumice. This material is similar to Bon Ami which may also be used. The pumice is used as a slurry with water and is applied to the surface with clean rags and bristle brushes.

3. Impregnated cotton wadding. Cotton which has been impregnated with a cleaning material is used for the removal of exhaust gas stains and for polishing corroded aluminum surfaces. It is also used on other metal surfaces to produce a high reflectance.

4. Aluminum metal polish. Aluminum metal polish is used to produce a high-luster, long-lasting polish on unpainted aluminum-clad surfaces. It is not used on anodized surfaces, as it will remove the oxide coat.

5. Aluminum wool. Three grades of aluminum wool–coarse, medium, and fine–are stocked for general abrasive cleaning of aluminum surfaces.

6. Lacquer rubbing compound, type III. For the removal of engine exhaust and minor oxidation, lacquer rubbing compound, type III, may be used. Heavy rubbing over rivet heads or edges where protective coatings may be thin should be avoided as the coverings may be damaged most easily at these points.

CHEMICAL CLEANERS.–Chemical cleaners must be used with great care in cleaning. The danger of entrapping corrosive materials in between layers of metal and at seams counteracts any advantages in their speed and effectiveness. All materials used must be relatively neutral and easy to remove. It is important that all residues from this type of cleaning be removed. Soluble salts from chemical surface treatments such as chromate acid or dichromate treatment will liquefy and promote blistering in the paint coatings.

1. Phosphoric-citric acid mixture. This chemical surface cleaner is available in types I and II. Type I is a ready-to-use prepackaged mixture. Type II is a concentrate which must be diluted with mineral spirits or water as required. The mixture is applied to the surface to be cleaned with a soft brush, rag, or sponge, using a circular brushing motion in order to loosen the surface film. After a 15-minute dwell time, this acid mixture should be thoroughly flushed from the cleaned surface with a stream of water.

2. Bicarbonate of soda. This material, commonly known as baking soda, should always be available to neutralize acid deposits as well as to treat acid burns from chemical cleaners and inhibitors. All battery holders, battery compartments of automotive vehicles, and electric powerplants are generally cleaned with this agent. It can also be used to clean tarnished silver contacts by placing the silver-coated part in contact with magnesium metal and

submerging the two in a water solution of baking soda and salt.

3. Ammonium hydroxide. In addition to baking soda, ammonium hydroxide also may be used as a neutralizing agent for acid in battery compartments and elsewhere. Treated areas should be rinsed thoroughly with water after use.

CLEANING EQUIPMENT.–Cleaning not only requires the use of correct cleaning materials, but also the use of proper equipment to produce efficient and satisfactory results. A specific cleaning area should be prepared and equipped for performing cleaning operations.

The choice of equipment depends upon several factors, such as the amount of cleaning that is regularly performed, the type of equipment that is being cleaned, the location of the activity, and the availability of facilities such as air, steam, and electricity.

Some of the equipment available for cleaning are pressure tank sprayers, high-pressure cleaning machines, immersion tanks, and industrial vacuum cleaners.

In addition to the equipment mentioned above, other items such as hoses, spray guns, brushes, sponges, and wiping cloths are required for cleaning. These items are procured through regular supply channels.

Items of personal protection such as rubber gloves, rubber boots, goggles, and aprons should be worn when necessary to protect the clothing and eyes from fumes and splashing of caustic materials.

CLEANING METHODS AND PROCEDURES.–The first step in cleaning an item of support equipment is to select the proper cleaning agent for the method of cleaning to be used. For some items of equipment, the recommended type of cleaning agent for each method and instructions and precautions to be observed in their use may be found in the applicable Instructions Manual. If this information is not included in the applicable manual, the instructions on the container of the cleaning agent must be followed.

The next step is the preparation of the item of equipment for cleaning. This step, of course, will vary with the type, size, and model of equipment. The equipment should be placed in a cool shady place if possible. Most items of equipment should be grounded to the deck during cleaning. Cleaning operations cause the buildup of static electricity, which is dissipated through the ground wire. After securing all the obvious openings such as access panels, further secure the equipment against entry of water and cleaning compounds. In addition, mask or otherwise cover all equipment or components that can be damaged by moisture or the cleaning agent being used.

Approved cleaning methods are listed as follows:

1. Water wash cleaning. The water wash method is recommended as the most efficient and satisfactory method of cleaning most items of support equipment when they are only lightly contaminated with dirt and grease. The equipment is prepared as previously outlined, and all cleaning materials and equipment that will be required during the cleaning operation should be on hand and ready for use. Prior to beginning the actual wash, the entire item of equipment should be wet down. The equipment is then washed using the prescribed cleaning solution and sponges or soft cloths.

After each step in the water wash procedure, the cleaning solution should be rinsed off with clean water. All cleaning solution must be removed from joints, recesses, and other possible places where it can collect. Surfaces are dried with clean sponges or soft cloths if necessary.

2. Emulsion cleaning. The emulsion cleaning method is used to clean areas contaminated with oil, grease, or other foreign matter which cannot be easily removed by other methods. The item of equipment is prepared the same as for the water wash method. Mix the emulsion in accordance with the Instructions Manual for the type of equipment concerned or the instructions on the emulsion container. The emulsion solution is applied to either wet or dry surfaces depending upon the type of emulsion. If it is the type that must be applied to wet surfaces, the surface should first be dampened with warm water. After application of the emulsion solution, a dwell time of 5 minutes is usually sufficient to loosen all contaminants. Rinse the area with high-pressure hot or cold water. If any areas are still not clean, repeat the

operation as necessary on these areas only. Finally, the surface is dried with a clean sponge or cloth. This is important after emulsion cleaning, as air-drying may leave the paint coatings streaked; especially if the surfaces were not adequately rinsed.

3. Steam cleaning. High-pressure, live steam and a suitable steam cleaning compound will remove the majority of soils with a minimum of manhours and time. With this method, one of several types of steam generating machines must be used. The types, operation, and maintenance of steam cleaners are covered in chapter 10 of *Aviation Support Equipment Technician (H)*, NAVEDTRA 10316-A.

Steam cleaning is a harsh cleaning method that is very effective when expertly accomplished, but can severely damage components and painted surfaces if improperly done. Extreme care should be exercised when steam or hot water is used. The nozzle should be held at an angle of 45 degrees to the surface being cleaned. The distance the nozzle is held from the surface depends upon the finish. In addition, the nozzle should never be held in one place too long or local overheating may result, causing damage to the components or surfaces of the equipment. It is necessary to provide cover protection for plastics, seals, and other materials which can be damaged by this cleaning method. Some manufacturers do not recommend the use of steam on painted surfaces.

CLEANING PRECAUTIONS.–Observe the following precautions to prevent damage to equipment which has been or is to be cleaned:

1. When equipment with unpainted metal surfaces has been cleaned and dried prior to applying preservatives, do not handle except by mechanical means or by wearing clean canvas or rubber gloves. Avoid touching cleaned and dried surfaces with bare hands, as perspiration is extremely corrosive. If, under emergency conditions, it becomes necessary to handle equipment with bare hands, remove the resultant fingerprints by the method outlined in the cleaning section of this chapter.

2. Handle equipment coated with preservatives by mechanical means only. If the preservative coating is abraded, restore the affected area after handling.

3. Clean metal surfaces tend to corrode in a short time. Apply preservatives as soon as possible after cleaning. If application of preservatives is delayed, coat the metal surfaces with a preservative lubricating oil until the specified preservative can be applied.

4. Slight changes in the temperature and humidity of the surrounding air may cause condensation of water on metal surfaces. When applying preservatives or lubricants to metal surfaces, maintain the temperature of the surface above the dewpoint of the ambient atmosphere, to prevent condensation and retention of water, which causes corrosion under the protective film.

5. Remove water condensed on the equipment or treat the equipment with a water-displacing compound before application of preservatives. If cleaning is performed out of doors under adverse weather conditions, shelter the operation with canvas or tarpaulins.

6. Process disassembled equipment indoors.

7. Avoid trapping cleaning materials within the equipment. Take special care to avoid contact of cleaning materials with optical surfaces, dials, electrical contacts, and painted surfaces.

8. Do not use immersion cleaning on any equipment containing nonmetallic materials, unless they will not be affected by the cleaners, or are masked for protection.

9. Do not use alkaline solutions such as those of soda ash, trisodium phosphate, or metasilicate for cleaning equipment with extremely close tolerances or highly finished surfaces.

10. Do not clean the following metals in alkaline solutions, unless the solution is specified for such purposes: Aluminum, aluminum alloys zinc, tin, terne, and lead.

11. Do not use acid or alkaline solutions to clean equipment having bolted or riveted assemblies, when there is a possibility of trapping cleaning solution between joined members. The solutions or their residues may cause corrosion and damage paint coatings. Do not allow organic materials to remain in contact with oxidizers.

12. Prepare acid cleaning solutions accurately, as excess acid may attack copper, brass, bronze, steel, and other metals.
13. Do not allow organic solvents to remain in contact with rubber, electrical insulation, or organic coatings.

Lubrication Materials

Lubrication is generally considered to be for reduction of friction and to aid in dissipation of heat; however, many lubricants are specifically compounded for the purpose of corrosion prevention.

The corrosion-inhibiting properties of a lubricant are almost equal in importance to its lubricating properties. In some applications it may be necesssry to reduce lubrication quality to obtain better protection against corrosion. Many metal parts are subject to corrosion when exposed to moist air. The application of oil or grease to a metal surface tends to protect it from air and moisture, thus retarding corrosion. It is essential that a lubricant selected for this purpose be one that will remain on the surfaces to be protected under adverse conditions of pressure and temperature, and be formulated so as to retard or prevent the formation of corrosive substances. Many of the lubricants discussed in this chapter contain corrosive inhibitors and other additives to improve stability and other properties.

Corrosion, particularly that resulting from continuous exposure to a marine environment, is a problem of major importance. Equipment which is in temporary stowage or standby condition must also be protected. In many instances, it is essential that equipment be protected in such a way that its return to active service will require only a minimum of change, such as removal of preservatives. Greases containing corrosion inhibitors are often used as preservatives because they possess lubricating qualities and need not be removed from the equipment when it is reactivated.

Lubricants for ground support equipment are selected on the basis of the following desired characteristics:

1. Maximum reduction of friction between the surfaces involved.
2. Corrosion-inhibiting quality.
3. Stability over a wide range of temperatures.
4. Ability to withstand high pressures.
5. Nonvolatility at operating temperatures.
6. High resistance to oxidation and consequent formation of acids, gums, sludges, and carbon.
7. Resistance to emulsification.
8. Maximum resistance to contamination under the environmental conditions of the particular application.

Although various lubricants are described herein and certain properties listed, the applicable specification should be consulted and all properties and characteristics of the material reviewed prior to its selection for a specific application.

It is not feasible to cover all the lubricants available to the fleet in this chapter. However, lubricants that are most commonly used for corrosion prevention are discussed.

OIL, PRESERVATIVE, HYDRAULIC EQUIPMENT.–This oil is used in the preservation of hydraulic systems and components, and is similar in appearance to, but is not interchangeable with, operating hydraulic fluid. Therefore, before using operating hydraulic fluid (MIL-H-5606C) or this preservative oil (MIL-H-6083) for any purpose, the specification number should be checked to ascertain that the correct oil is being used. The preservative oil contains oxidation and rust inhibitors, viscosity improver, and antiwear agents. Hydraulic parts and components being turned in for screening and repair are flushed and drip drained with MIL-H-6083 oil prior to being forwarded.

Designed primarily for hydraulic components, this oil may be used on any bare critical surface that needs protection. Operating hydraulic fluid will protect a steel panel immersed in water for only about 48 hours. The same metal panel coated with MIL-H-6083 inhibited hydraulic oil will show 100 percent protection for a period of 30 days or more.

LUBRICATING OIL, GENERAL PURPOSE, PRESERVATIVE VV-L-800.–There are several different types of lubricating oil, some of which contain preservatives. In order to be absolutely sure that the proper oil is used in a given situation, each must be identified with its specification number. The specification number for the oil discussed in this section is VV-L-800.

VV-L-800 oil was compounded for lubrication and protection of systems whenever a water-displacing, low-temperature, lubricating oil is required. Many manufacturers recommend this oil for use in external piano-type hinges, as it will force out and take the place of any water entrapped between the hinge pin and the tangs.

LUBRICATING OIL, GENERAL PURPOSE, LOW TEMPERATURE.–This general purpose oil (specification number MIL-L-7870) is interchangeable with VV-L-800 oil and is recommended over VV-L-800. It is suitable for use anywhere that a general purpose lubricating oil with low-temperature, low-viscosity, and corrosion-preventive properties is required.

Application may be by brush, spray, dip, or general squirt can. It is not necessary to remove before reoiling or for inspection.

LUBRICATING OIL, PRESERVATIVE, MEDIUM, MIL-L-3150.–This is a mineral base, medium grade lubricating oil with inhibitors for the protection of ferrous and non-ferrous metals.

MIL-L-3150 is intended for use in preserving some equipments for periods of 30 days or more. Equipments preserved with this material must be cleaned and relubricated before use. The lubricant can be readily removed with Stoddard Solvent P-S-661.

It may be applied by the brush, dip, or spray method in temperatures above 20°F.

Lubrication Instructions

For proper lubrication of the various components of ground support equipment, such as bearings, sliding parts, linkages, and gearing, follow the lubrication charts and instructions furnished for the particular equipment or for the general type of equipment. The charts and instructions are revised frequently, and it is important that the latest revision be used, as the applicable manuals accompanying the equipment do not necessarily agree with the current lubrication instructions and charts.

LUBRICANT CONTAMINATION.–Prevention of either accidental or deliberate contamination of lubricants and fluids used in ground support equipment is of great importance. Foreign materials such as dirt, metal particles, and water may render equipment inoperable or cause severe wear or damage. Even minute foreign particles can affect adjustment or cause faulty operation of delicate instruments. The following precautions should be strictly observed:

1. All surfaces, fittings, oil and grease cups, and applicators such as grease guns, oil cans, pressure lubricators, spray guns, spatulas, and brushes should be thoroughly cleaned before using.
2. Containers of lubricants and fluids should be kept tightly closed when not in use and should be carefully protected against entrance of foreign materials when opened.
3. Material which is suspected of being contaminated, because of its unusual appearance, should not be used unless close examination reveals that it is free of solid particles, or tests show it to be in conformance with the requirements of the applicable specification.
4. Workshop or shipboard locations where lubrication or preservation is carried on should be kept clean and orderly.

CORROSION REMOVAL

Corrosion removal operations and methods vary considerably, and are dependent mainly upon the type of material of which the equipment is constructed. Approved methods of corrosion removal for several types of metal are described briefly in the following paragraphs.

Corrosion Removal from Aluminum

There are three types of aluminum surfaces insofar as corrosion removal is concerned. They are clad, anodized, and exfoliated.

CLAD ALUMINUM SURFACES.–Pure aluminum has considerable corrosion resistance compared to aluminum alloys, but has little or no structural strength. It has been learned that an extremely thin sheet of pure aluminum laminated onto each side of an aluminum alloy sheet improves the corrosion resistance with little impairment of strength. The trade name of this aluminum laminate, as originated by the Aluminum Company of America, is "Alclad". From this trade name has derived the adjective "clad" and the verb "cladding". Not all sheet aluminum is clad, especially those alloy sheets from which small brackets, gussets, fittings, etc., are made. Pure aluminum is very soft, and the fabrication processes would severely damage or destroy the clad surfaces.

To remove corrosion from clad surfaces the corroded areas should be hand polished with household abrasives such as Bon Ami or Ajax, or with a specified metal polish, MIL-P-6888. The specified polish effectively removes stains and produces a high-gloss, lasting polish on unpainted clad surfaces. If a surface is particularly difficult to clean, Compound, Cleaner and Brightener, Aircraft Surfaces, type II (specification MIL-C-5410), may be used. Mixed 50-50 percent with solvent or mineral spirits, this compound used before polishing will shorten the time and lessen the effort necessary to get a clean surface. During both the foregoing polishing and brightening operations, care must be taken to avoid unnecessary mechanical removal of the protective clad layer and the exposure of more susceptible, but stronger, aluminum alloy base.

If there is any superficial corrosion present, it should be treated by wiping down with an inhibitive material such as the Chemical Surface Films for Aluminum Alloys, available under specification MIL-C-5541. Allow the solution to remain on the corroded area for 5 to 20 minutes, and then remove the excess by wiping the surface dry with clean cloths. If the Alclad material is to be used in the unpainted condition, it may now be overcoated with an approved wax which is of the waterproof, solvent type. If the treated Alclad surface is to be painted, no wax is used, and the paint pretreatment is applied instead.

ANODIZED ALUMINUM SURFACES.–Anodizing is the most common surface treatment of nonclad aluminum alloy surfaces. The aluminum alloy sheet or casting is the positive pole in an electrolytic bath in which chromic acid or other oxidizing agent produces an aluminum oxide film on the metal surface. Aluminum oxide is naturally protective, and anodizing merely increases the thickness and density of the natural oxide film. When this coating is damaged in service, it can be only partially restored by chemical surface treatments. Therefore, any processing of anodized surfaces, including corrosion removal, should avoid unnecessary destruction of the oxide film.

Aluminum wool, aluminum wire brushes, or fiber bristle brushes are the approved tools for cleaning anodized surfaces. The use of steel wool, steel wire brushes, or harsh abrasive materials on any aluminum surfaces is prohibited. Producing a buffed or wire brush finish by any means is also prohibited. Otherwise, anodized surfaces are treated in much the same manner as other aluminum finishes.

EXFOLIATED SURFACES.–Exfoliation is a separation along the grain boundaries of metal and is caused by intergranular corrosion. More severe procedures must be observed when intergranular corrosion is present. The mechanical removal of all corrosion products and visible delaminated metal layers must be accomplished in order to determine the extent of destruction and to evaluate the remaining structural strength of the component. Metal scrapers, rotary files, and other necessary tools are used to assure that all corrosion products are removed and that only structurally sound aluminum remains. Inspection with a 5- to 10-power magnifying glass, or the use of dye penetrant, will aid in determining if all unsound metal and corrosion products have been removed. When complete removal has been attained, any rough edges should be blended or smoothed out even though this involves the removal of more metal. Grinding, where required, can best be accomplished by using rubber base wheels into which tiny particles of aluminum oxide abrasives have been impregnated.

Chemical treatment of exposed surfaces is applied in the same manner as any other aluminum surface.

Corrosion Removal From Iron and Steel

The most practical means of controlling the corrosion of steel is the complete removal of the corrosion products (rust) by mechanical means. Except on highly stressed steel surfaces, the use of abrasive papers, small power buffers and buffing compounds, hand wire brushing, and steel wool are all acceptable cleanup procedures. It is a recognized fact, however, that in any such uses of abrasives, residual iron rust usually remains in the bottom of small pits and other surfaces. As a result, a part once rusty usually corrodes again, and more easily than it did the first time.

There are approved methods for converting active iron rust to phosphates and other protective coatings; however, most of these procedures require shop installed equipment and are therefore impractical in the field. Another disadvantage of chemically inhibiting iron rust is the danger of entrapping these chemicals in installed assemblies where thorough flushing is difficult, thereby causing far more corrosion than was originally present.

CADMIUM-PLATED SURFACES.–Cadmium platings are still offering sacrificial protection even when they show mottling ranging from white to brown to black on their surfaces. This discoloration should never be removed for the sake of appearance alone. Not until the characteristic color peculiar to corrosion of the base metal appears should steps be taken.

Corrosion present should be removed by rubbing lightly with stainless steel wool. Under no circumstances should a wire brush, stainless or otherwise, be used on cadmium-plated surfaces as these will remove more plating than corrosion. After the corrosion has been removed, the affected area should be swabbed with a chromic acid solution and, after 30 to 60 seconds, rinsed with clean water and dried with clean cloths or low-pressure compressed air. The part is then ready for a protective paint coating.

STAINLESS STEEL ALLOY SURFACES.–When processing corroded stainless steel surfaces in the field, the following precautions must be considered:

1. Stainless steel surfaces are never wire brushed under any condition.
2. If removal of heat scale is necessary, the part should be removed and sent to the nearest depot maintenance activity for the proper chemical treatment.
3. In some cases, stainless steel components may be cleaned by light blasting with 100-mesh garnet or the equivalent at a pressure not to exceed 40 psi; however, this requires special equipment that is not generally available in the field.

Corrosion Removal From Magnesium

Magnesium corrosion reprotection involves the maximum removal of corrosion products, the partial restoration of surface coatings by chemical treatment, and a reapplication of protective coatings.

After cleaning the surface and stripping the paint, if any, as much of the corrosion products as possible should be broken loose and removed using a stiff bristle brush. Steel wire brushes, carborundum abrasives, or steel cutting tools should not be used.

The corroded area is treated liberally with a solution of chromic acid and battery electrolyte. The solution is worked into pits and crevices by brushing the area while still wet, again using a bristle rather than a metal brush. After the chromic acid solution has remained in place from 5 to 20 minutes, the excess should be wiped off with a damp cloth. If an excess of the solution is allowed to dry on any painted surfaces, the paint film will be ruined. As soon as the surfaces are dry after the damp cloth wiping, the original protective paint scheme should be restored.

Corrosion Damage Limits

The term "corrosion damage limits" refers to the amount of metal which may be removed from a corroded part and still maintain the required safe margin of strength and function. When removing corrosion, maintenance personnel must be very careful not to remove more of the metal than is absolutely necessary to ensure complete removal of corrosion.

Damage which exceeds those limits specified in the applicable Structural Repair Manual or the Corrosion Control section of the applicable Instructions Manual necessitates replacement of the affected part if actual structural repair of the damage is not possible or feasible.

One of the biggest problems in corrosion control is in knowing what materials to use, where to find them, and the limitations applicable to their use. Materials used should be those covered and controlled by military specifications. Corrosion control information pertaining to materials, methods, and techniques is scattered throughout many directives and instructions. The following is a list of sources of information that should be available for reference in every unit's technical library or in the ground support equipment shop:

1. Corrosion Control for Aircraft, NAVAIR 01-1A-509.
2. Preservation of Naval Aircraft, NAVAIR 15-01-500.
3. Preservation of Aircraft Engines, NAVAIR 15-02-500.
4. Chart–Chemical Materials for Naval Weapons Systems–Maintenance and Overhaul Operations, NAVAIR 07-1-503.

CHAPTER 15

ENVIRONMENTAL POLLUTION CONTROL

When it first began to dawn on people that the environment was worsening, that blight was creeping across our land, that the air was polluted and the waters running with waste, the Navy took steps to lessen its contribution to all the varieties of pollution. In the face of this challenge, Navy training and education of the ASM must be broadened so that he can have the knowledge to combat this effect on our environment; thus, the inclusion of this chapter in this manual.

AIR POLLUTION

The contamination of the air with unwanted gases, smoke particles, and other substances is generally considered a recent phenomenon. However, pollution of the air, particularly with smoke, has plagued communities since the dawn of the Industrial Revolution. By the latter part of the 19th century complaints against air pollution were registered in Europe as well as in the United States. Records show that pollution control laws were adopted by Chicago and Cincinnati as early as 1881, and that by 1912, most American cities with populations over 200,000 has smoke abatement ordinances.

Although historical records do not offer any assurance that a significant amount of pollution was ever controlled under these laws, it was a beginning. These local control efforts were focused primarily on reducing smoke from fossil fuels, particularly coal, by regulating the types of coal that could be burned, by improving combustion practices, and, in some cases, by the application of special devices to control emissions of particles into the air.

During the 1940s, a new type of air pollution problem was emerging. When the citizens of Los Angeles began to complain of smog, few people suspected that the problem of smoke pollution and the general problem of air pollution are not the same. Los Angeles used virtually none of the fuels primarily responsible for the smoke problems of other cities; yet, the smog became worse. It was later discovered that the Los Angeles smog was not due primarily to smoke in the air but to the action of sunlight on certain of the gases emitted by car exhausts.

CLASSES OF POLLUTION

Five main classes of pollutants are pumped into the air over the United States, totaling more than 200 million tons per year. The five pollutants are carbon monoxide, particulate matter, sulfur oxides, hydrocarbons, and nitrogen oxides.

Carbon Monoxide

Carbon monoxide is a colorless, odorless, poisonous gas, slightly lighter than air, that is produced by the incomplete burning of the carbon in fuels. Carbon monoxide emissions can be minimized by supplying enough air to ensure more complete combustion. When this happens, carbon dioxide (CO_2), a natural constituent of the atmosphere, is produced instead of carbon monoxide.

Almost two-thirds of the carbon monoxide in the air we breathe comes from internal combustion engines, and the overwhelming bulk of that comes from gasoline-powered motor vehicles. This is one of the most common pollutants, and when inhaled, it displaces the oxygen in the blood and reduces the amount of oxygen carried to the body's tissues. At levels commonly found in the air, it can affect the reactions of even the healthiest persons, making them more prone to accidents.

Studies show that exposure to 10 parts carbon monoxide per million parts of air (ppm) for approximately 8 hours can affect a person's mental performance. Such levels of carbon monoxide are commonly found in cities throughout the world. In heavy traffic, levels of 70, 80, or 100 ppm are not uncommon.

The elimination of carbon monoxide is generally treated along with nitrogen oxides and hydrocarbons, as these pollutants cannot be treated separately in the case of automotive exhaust emissions.

This may be done by controlling the pollutants with proper tune-ups and correct emission equipment that will cause the vapors from fuel to be burned in the engine. Intensive research is under way to improve auto emission controls and to modify fuels to reduce the emissions of nitrogen oxides, hydrocarbons, and carbon monoxide.

Particulate Matter

Particulate matter includes particles of solid or liquid substances in a very wide range of sizes, from those that are visible as soot and smoke to particles too small to detect except under an electron microscope. Particulates may be so small that they remain in the air for long periods and can be transported great distances by the winds. They are produced primarily by stationary fuel combustion (31 percent) and industrial processes (27 percent). Forest fires and other miscellaneous sources account for 42 percent.

The lowest particulate levels at which health effects have been noted in the United States have been reported in studies at Buffalo, N.Y. The Buffalo findings suggest that the overall death rate increases in areas with an annual average concentration ranging from 80 to 100 micrograms per cubic meter. This study also reveals an association between these levels of particulate matter and gastric cancer in men 50 to 69 years old, and a similar association was found in a Nashville, Tenn., study. Particulate levels in this range are found in most major urban areas and are common even in smaller industrial cities.

A number of particulates present special health hazards. Beryllium, for example, which may be emitted from industrial sources and in smaller amounts from its use in rocket fuel, can cause lesions in the lung, leading to serious respiratory damage and even death.

Asbestos, long recognized as presenting an occupational hazard, is increasingly present in the air from its use in construction materials, brake linings, and other products. Long exposure produces the lung scarring disease asbestosis. On the other hand, heavy or continued exposure does not necessarily produce mesothelioma, a type of lung cancer associated almost exclusively with asbestos exposure.

A host of other particulates are of growing concern even though they may not constitute such an immediate and direct threat. For example, current studies suggest that lead levels now being found in the blood and urine of urban residents, although below those associated with classic lead poisoning, may affect the ability of the body to produce blood cells and may have unsuspected adverse effects, particularly in children. As air pollution becomes more widespread, increasing numbers of people are being exposed to airborne lead, chiefly from car exhausts, at levels formerly found only in congested areas.

There are established techniques for controlling particulates from a boiler stack or from a waste air stream, among them are filtering, washing, centrifugal separation, and electrostatic precipitation. These work well for most of the particles, but complete removal, especially of the very finest particles, is technically and economically difficult.

Sulfur Oxides

Sulfur oxides are acrid, corrosive, poisonous gases produced when fuel containing sulfur is burned. Electric utilities and industrial plants are its principal producers since their most abundant fuels are coal and oil, which contain sulfur as an impurity. The burning of coal produces about

60 percent of all sulfur oxide emissions, oil about 14 percent, and industrial processes that use sulfur, 22 percent. Most of the coal and oil is burned in electric power generation plants. About two-thirds of the nation's sulfur oxides are emitted in urban areas, where industry and population are concentrated.

These sulfur oxides can cause both temporary and permanent injury to the respiratory system. When sulfur oxides are inhaled along with particulate matter, the health damage increases significantly. Sulfur dioxide gas alone can irritate the upper respiratory tract. Health may be affected adversely when the annual mean concentration of sulfur dioxide in the air rises above 115 micrograms (115 milligrams) per cubic meter (35.3 cubic feet). American cities often substantially exceed this annual mean.

Government agencies and industry have sought to reduce sulfur oxide emissions in three ways: switching to low sulfur fuels (those with less than 1 percent sulfur), removing sulfur from fuels entirely, and removing sulfur oxides from the combustion gases.

Hydrocarbons

Hydrocarbons, like carbon monoxide, represent unburned and wasted fuel. Unlike carbon monoxide, gaseous hydrocarbons at concentrations normally found in the atmosphere are not toxic, but they are major pollutants because of their role in forming photochemical smog. Nitrogen oxides, when in the presence of sunlight, combine with gaseous hydrocarbons to form a complex variety of secondary pollutants called photochemical oxidants. More than half the estimated 32 million tons of hydrocarbons produced each year comes from transportation sources, mainly gasoline-fueled vehicles. Another 27 percent comes from miscellaneous burning and 14 percent from industrial processes. About 60 percent is produced in urban areas, largely because there are more automobiles.

Nitrogen Oxides

Nitrogen oxides are produced when fuel is burned at very high temperatures. Stationary combustion plants produce 49 percent of the nitrogen oxide emissions; transportation vehicles, 39 percent; and all other sources, 12 percent.

Internal combustion engines operate at very high temperatures, and so do efficient, large electric power and industrial boilers. Nitrogen that is ordinarily inert combines with oxygen in high temperature flames and tends to stay combined if the exhaust gases are cooled too quickly. The control of nitrogen oxides from stationary sources requires careful adjustment of flames and stack gas temperatures. Control of nitrogen oxides from automobiles is more difficult because reducing other pollutants can increase the output of nitrogen oxides.

Under the influence of sunlight, nitrogen oxides combine with gaseous hydrocarbons to form a complex variety of secondary pollutants called photochemical oxidants. These oxidants, together with solid and liquid particles in the air, make up what is commonly known as smog. The photochemical oxidant family of pollutants can cause eye and lung irritation, damage to vegetation, offensive odor, and thick haze.

Reducing sulfur discharges from ships has proven to be a difficult job. Starting in 1967, the Navy developed a new type of fuel oil called Navy distillate fuel. This fuel reduces smoke and sulfur dioxide emissions very significantly. It is a clean-burning fuel and an intensive program is underway to convert all conventionally powered ships to this new type of fuel.

CONTROLLING POLLUTION

In the United States there are a variety of Federal, state, and local programs aimed at combating air pollution. The first Federal program dealing with air pollution was created in 1955, when Congress enacted legislation authorizing Federal research into the problem while also giving technical assistance to state and local governments. This legislation established the Federal policy that state and local governments have a fundamental responsibility for dealing with community air pollution problems and that the Federal government has an obligation to provide leadership and support. This policy is still in effect, and all Federal air pollution programs are carried out by the National Air Pollution Control Administration (NAPCA).

In 1963 the U.S. Congress enacted the clean air act, which authorized two new major Federal activities to support air control efforts throughout the country and the awarding of grants directly to state and local agencies to assist them in developing, or improving control programs. It also assigned the Federal government new responsibilities for the research on two important aspects of the Federal pollution problem, motor vehicle pollution, and sulfur dioxide pollution. In addition, it gave the Federal government the responsibility of developing criteria to evaluate the effects of air pollution on health and property. In 1965 the clean air act was amended to enable the NAPCA to establish standards of motor vehicle pollution. Briefly, here is what the Navy has done to reduce pollution from crankcase and exhaust emissions.

During the combustion process in a gasoline engine, gases seep past the piston rings into the crankcase. These gases are the result of burned and unburned fuel and oil in the combustion chamber. The seepage, called blowby, moving past the rings is the result of:

1. High combustion chamber pressures.
2. Necessary working clearance of piston rings in their grooves.
3. Normal ring shifting that sometimes lines up clearance gaps of two or more rings.

If blowby is not removed from the crankcase, it condenses in the crankcase to form sludge and to cause oil dilution.

In 1963, The Positive Crankcase Ventilation (PCV) system was introduced on all newly manufactured cars. However, this system had been used on military vehicles long before this to combat sludge problems. The first systems used the OPEN PCV system. This system uses manifold vacuum for its vacuum source. Fresh air enters an open PCV system through a vented oil filler cap, mixes with the crankcase vapors in the crankcase, and is metered through a PCV valve into the intake manifold. Here it blends with the fuel air mixture being delivered by the carburetor to be burned in the combustion chamber.

Starting in 1968, all new cars and trucks have been equipped with the CLOSED PCV system. The closed PCV system is similar in operating principle to the open system except that fresh air enters the closed system from the clean air side of the air cleaner or a separate PCV breather filter on the inside periphery of the air cleaner.

Most open and closed systems normally use a PCV valve. However, some installations use a fixed orifice instead of a valve. In some instances, the metering orifice is in the oil filler cap. In these systems, the air flow in the PCV system is not regulated, but only restricted. This is referred to as the tube-type ventilation system. Regulation of the air fuel ratio is accomplished through carburetion alone, since the orifice size is fixed and cannot be varied during operation.

Excessive (visible) exhaust emissions are due primarily to incomplete combustion in the combustion chamber. The automobile manufacturers use different means to control these emissions and likewise use different general terms to identify their systems.

During deceleration the fuel air ratio is very rich in the area of the exhaust valve. If the air pump system were allowed to operate under this condition, back-firing conditions would result as soon as the fresh air from the pump mixed with overly rich vapor to produce a combustible mixture. A vacuum-operated diverter valve (bypass valve) prevents this by dumping air pump output into the atmosphere during the deceleration period. (Some installations divert the air pump output directly back to the air pump itself.)

In addition to or substituting for the air pump, most cars manufactured beginning in 1968 use modified carburetion (resulting in cleaner fuel air ratios), revised ignition timing, and hotter thermostats.

Motor vehicle pollution is the product of a complex combustion system of engines, fuels, and fuel additives. Effective control, then, means dealing not only with engines and control devices but with the fuel itself and with fuel additives.

Air injection was the first step toward the control of exhaust emissions. This is commonly referred to as an AIR PUMP system. It was first used in 1966 and 1967 on some cars and, beginning in 1968, was rather widely used on many cars. The following is a trade description of the air pump as offered by some manufacturers.

The system consists of an air pump, air manifold, check valve, and diverter valve. Most pumps use a relief valve in the side of the pump housing which relieves the pressure built up in the pump if it exceeds a predetermined value.

In operation, compressed air from the pump is distributed through a manifold to the pipe extension or jet behind each exhaust valve. The injection of air at this point causes those unburned fuel and oil particles and other by-products of combustion to burn in the exhaust manifold as they leave the cylinder head rather than pass out to the atmosphere through the exhaust pipe.

The check valve prevents exhaust gases from entering the pump should pump or drive belt failure occur.

The key undesirable additive from an air pollution control view point is tetraethyl lead in gasoline. It accounts for a significant portion of the particulate pollution from automobiles. Some gasoline manufacturers are producing gasoline that is almost lead-free. However, some premium gasolines containing lead will still be needed for a number of years to meet the requirements of high compression engines in older cars.

Jet engines also contribute their share of pollutants to the air. Present Navy efforts toward reduction of air pollution by jet engines are being directed along two channels: (1) improvement of engines and (2) removal of particulate matter from engine test cell exhausts.

To date, the Navy has spent money on development of smokeless combustors and the retrofitting of new combustor cans in certain engines. Replacement of combustor cans in the TF-30-P-8 and J52-P-8 engines has been completed. More money and effort will be spent to develop acceptable designs and prototypes to eliminate smoke from the TF 41, TF 30-P-6, T56, J79 and J57 models.

New naval aircraft engines will be equipped with smokeless combustors. These are the F14, S3 and engines for new heavy-lift helicopters.

It is expected that, by 1976 or 1977, all naval combat aircraft will be equipped with smokeless combustors and will comply with regulations on visible emissions.

Studies have been made of several systems for controlling emissions from jet engine test cells. A system called a "nucleation scrubber" or wet scrubber facility seems promising. It is expected to remove 99 percent of the noxious gases from engine test cell emissions.

The Navy, with the cooperation of Pratt and Whitney, has carefully evaluated the use of fuel additives, including Ethyl "CI-2", both in engine test cells and in flight. Tests have indicated degradation of engine performance and in some cases compressor stalls, a very unacceptable condition. Use of this additive has also resulted in deposits of hard residues on surfaces of internal engine parts, significantly increasing maintenance.

WATER POLLUTION

There are several Federal laws governing air and water quality standards, when they must be achieved, and punishments for violations. In conjunction with these laws there are several Navy instructions concerning procedures to be followed by ships and shore installations to abate pollution of the environment in general, and of waters in particular. Several basic, biological, chemical, and physical processes affect the quality of water. Since this text can only generalize, water pollution will be divided into two categories: organic waste, and oil.

ORGANIC WASTE

Organic wastes (natural products such as food, paper, human waste) decompose by bacterial action. Bacteria attack wastes dumped into rivers and lakes, using up oxygen in the process. Fish and other aquatic life need oxygen. If the waste loads are so great that large amounts of oxygen are spent in their decomposition, certain types of fish can no longer live in that body of water. A pollution-resistant lower order of fish, such as carp, replace the original fish population. The amount of oxygen in a water body is therefore one of the best measures of its ecological health.

If all the oxygen is used, an anaerobic (without air) decomposition process is set in motion with a different mixture of bacteria. Rather than releasing carbon dioxide in the decomposition process, anaerobic decomposition releases methane or hydrogen sulfide. In these highly polluted situations, the river turns dark, and odors–like rotten eggs–penetrate the environment.

Heated water discharged into lakes and rivers often harms aquatic life. Heat accelerates biological and chemical processes, which reduce the ability of a body of water to retain dissolved oxygen and other dissolved gases. Increases in temperature often disrupt the reproduction cycles of fish. By hastening biological processes, heat accelerates the growth of aquatic plants–often algae. Finally, the temperature level determines the types of fish and other aquatic life that can live in any particular body of water. Taken together, these effects of excess heat operate to change the ecology of an area–sometimes drastically and rapidly.

One of the most serious water pollution problems is eutrophication–the "dying of lakes". All lakes go through a natural cycle of euthrophication, but normally it takes thousands of years. In the first stage lakes are deep and have little biological life. Lake Superior is a good example. Over time, nutrients and sediments are added; the lake becomes more biologically productive and shallower. This stage has been reached by Lake Ontario. As nutrients continue to be added, large algal blooms grow, fish populations change, and the lake begins to take on undesirable characteristics. Lake Erie is now in this stage. Over time, the lake becomes a swamp and finally a land area.

Man greatly accelerates this process of eutrophication when he adds nutrients to the water–detergents, waste food products, fertilizers, and human wastes. He has done this in Lake Erie and countless other lakes. Man's action can, in decades, cause change that would take nature thousands of years.

We've mentioned above the harmful effects of polluted waters on the natural environment, but what about water pollution's effect on human health?

Epidemics of typhoid, dysentery, and salmonellosis borne by polluted water are no longer serious public health threats in the United States. However, to maintain adequate protection of the public from these and other pollution dangers, water must often be treated to high levels before it is drinkable. Beaches often must be closed and shellfish left unharvested and unmarketed. Inadequately disinfected municipal wastes, overflows from combined sewer systems, and runoff from animal feedlots often create high bacteria densities in local water supplies. Ships that are anchored far up-stream can contribute to a high bacteria count in a community's water supply. The Navy is exploring the use of many devices and schemes to lessen the effect of waste discharges on water. Some of them are discussed in the following paragraphs.

Because there have been no constraints on the quality of effluent (nutrients, etc) in the past, optimum damage resistance and minimum cost design for Navy ships dictated a minimum penetration of water tight bulkheads and decks. This led to direct overboard discharge of all waste drains and soil drains into rivers, bays, estuaries, and the high seas at the nearest point of approach of the hull plating from the head or washrooms. Carriers, for example, have as many as 150 discharge hull penetrations.

The Water Quality Improvement Act of 1970, PL 91-224, dated 3 April 1970, stipulates that the environmental protection agency would set the sewage system effluent standards. This law also stipulates that existing ships including those under construction would have to be backfitted within five years after the sewage system effluent standards were promulgated. Ships constructed after this date must meet the standards within 2 years.

The Navy has funded research and development on Marine sanitation devices. These are: (1) Aerobic Systems, (2) the Macerator-Chlorinator, (3) the Recirculation Flush-sludge Storage System, (4) 175-Man

Fairbanks-Morse System, and (5) the 500-Man Fairbanks-Morse System.

Aerobic systems for shipboard use have not been successful, and the Navy terminated this effort several years ago. Both the Coast Guard and the EPA also terminated further development of these basically small extended aeration biological systems for shipboard use.

The Macerator-Chlorinator system merely grinds the solids into small particles and mixes the raw sewage with hypochlorite. Some chemical reaction occurs to reduce biochemical oxygen demand (a measure of the amount of oxygen needed to decompose wastes) and most of the organisms are destroyed. This unit is simple to install and operate and is lowest in cost, weight and space problem. However, operational experience with these systems found them unreliable, and the discharged chlorine presented another pollution problem.

The Recirculation system uses water to circulate the solid sludge to a holding tank where the water is removed and the concentrated sludge is stored. This system is similar to that used on commercial aircraft. The water is treated by chemicals and is recirculated in the system. The concentrated sludge is cleaned out when the ship is at sea or is connected to a shore sewage line. It is simple, low cost and requires low space and weight for installation. However, holding capacity is limited and this places a constraint on ship operations. One manufacturer of a system of this type is developing an incinerator to burn the sludge.

With all this effort and time, the Navy has yet to develop what can be considered a system that has proven reliable, maintainable and safe. Obviously, ship sewage disposal is the most difficult Navy problem to solve. Currently, we have 24 different proposals under evaluation and are encountering problems of performance and equipment reliability. The Navy must be absolutely certain that a completely reliable system is available before we start installing equipment on 700 naval ships at a cost now estimated to exceed $300 million.

OIL POLLUTANTS

Oil is probably the most obvious physical pollutant. Oil spills, as a result of collisions, and bilge or ballast discharges, put a coating on everything they touch. Oil makes beaches unusable and requires costly cleanup operations; it fouls boat hulls, pier pilings, and shore structures; and it degrades the esthetic nature of the environment.

The Navy's problems are not those generally caused by massive oil spills—but by the small spills in harbors, which are caused by leaks in systems, overflows through vent pipes on ships, fuel line parting during oil transfers and recovering operations, and human errors. Cleaning up those oil spills is time consuming, difficult, costly and often results in claims against the Government. Also, such spills create a serious fire hazard, are harmful to fish, shellfish and wild life; cause damage to watercraft; deny unrestricted use of bathing beaches and other private property; can contaminate water supply systems; and be displeasing.

This oil spill problem became acute with the signing of "The Water Quality Improvement Act of 1970" where the Congress declared "That it is the policy of the United States that there should be no discharge of oil into or upon the navigable waters of the United States, adjoining shorelines, or into or upon the waters of the contiguous zone, i.e., except those quantities as determined by the President."

The President through his enforcement agency, the Environmental Protection Agency (EPA), has established regulations which prohibit oil spills which "cause a film or sheen upon or discoloration of the surface of the water of adjoining shorelines or cause a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines."

PREVENTIVE MEASURES

The Navy's oil pollution abatement problem and solutions are being approached from several directions. Fleet commanders, Sea Frontier commanders and commandants have an active program to reevaluate existing operational procedures.

Education, increasing training measures with relation to oil problems, and better preventive maintenance techniques, both ashore and afloat, are contributing a marked reduction in oil spills.

Containment of Oil at Source

To this end the Navy is programming the procurement of thousands of feet of oil booms for containing oils close to the source of a spill. The Naval Research Laboratory in Washington, D. C. is studying how to control and confine oil spills using surface films. There are a series of organic chemicals which form very thin surface films (monomolecular layers) capable of driving oil across a water surface, increasing the oil-layer thickness, and reducing its area of coverage. A thicker oil layer occupying a smaller water surface area simplifies any recovery operation. More importantly the surface films can be used to prevent spreading of an oil spill; chemical boom effect. The oil-control films are largely insoluble in both oil and water and spread into extremely thin layers, usually only one molecule thick. Consequently, small quantities can cover large water surface areas and provide oil control and confinement.

Current research is directed toward the selection of ideal materials for this application which are nontoxic and acceptable to the Environmental Protection Agency for use in rivers, harbors, and estuaries.

Removal or Recovery of Oil from Within the Containment Area

The Navy policy is to physically remove oil from waters and to restrict the use of chemical emulsifiers, dispersants, and sinking agents primarily to incidents which reduce hazard to human life or where there is substantial hazard of fire to property. Realizing that oil spills will inevitably occur in spite of our best efforts, the Navy is establishing at each of its major naval ports an "in house" rapid response capability to clean up moderate oil spills emanating from naval vessels or shore facilities. At most naval facilities this capability will team up with contractors and other Federal agencies, or join into municipal or industrial oil removal coops. In an effort to provide adequate equipment to do the job, the Navy has embarked on a Joint Funded Demonstration project for an oil skimming device with the Environmental Protection Division. The skimmer employs the inverted weir principle which takes advantage of the buoyant properties of oil. The oil is carried under the skimmer device and is captured in a chamber, essentially water free, for removal to storage areas.

Another promising device consists of a rotating multidisc drum that looks somewhat like a harrow as it turns in the water. As the drum passes over the oil and water, the oil adheres to the rotating discs. A wiping device cleans the disc and sends the oil through a collection pipe to a storage area.

Oil Spill on the High Seas

We are all familiar with the massive oil spill problem associated with the Torroy Canyon tanker casualty off the coast of England and the Olean Eagle off San Juan, Puerto Rico. These accidents have generated national and international concern over the technical and managerial aspects of the problem.

The primary responsibility for mobilizing personnel and material resources against such major hazards rests with the U.S. Coast Guard, Department of Transportation, and the Federal Water Quality Administration, Department of the Interior. However, the recognized capability of the Navy to operate widely and diversely in the sea environment makes it natural for naval forces to be called upon to assist in these major oil pollution catastrophies.

The deliberate pollution of the high seas by petroleum and petroleum products is causing concern to all nations of the world. To this end the NATO Committee on the Challenges to Modern Society met in Brussels to develop action resolutions to combat pollution of the sea by oil spills. The committee developed Navy resolutions which will have a major impact on the operation of vessels on the high seas in the near future.

The President stated in his message to the Congress of 20 May 1970 that the threat of oil pollution from ships at sea and in harbors represented a growing danger to our marine environment and any remedy must deal with this problem on a global basis. To initiate impetus for effective international cooperation in alleviating the threat of oil spills on open waters, and to demonstrate the highest level of interest, the President appointed the Secretary of Transportation as Chairman of the U.S. Delegation represented at the November 1970 NATO Committee on Challenges of Modern Society (CCMS) Oil Spill Conference in Brussels. The Secretary of Transportation in his address to the Conference stated that "The United States. . .is fully committed to a priority national policy of improving and safeguarding environmental quality. Few problems in this field are so pressing or so readily evident as those posed by ocean oil pollution . . My government proposes that NATO nations resolve to achieve by mid-decade a complete halt to all intentional discharges of oil and oily wastes into the oceans by tankers and other vessels. This is a fundamental and major goal; it may involve steps such as improved ship design aimed at clean ballast operations and the development of adequate port facilities to receive waste, oily bilge and ballast waters." The nations of NATO adopted this position in a slightly modified tone as one of their major goals. In order for the Navy to respond effectively to this formidable task requested by the Administration and to demonstrate continued Navy leadership in the field of pollution abatement, the Navy initiated a survey of existing Naval Shore Facilities and ships to determine the following:

1. The current capability and capacity for handling, processing, reclaiming and/or disposing of bilge and ballast oily wastes from U.S. Naval vessels which will be required by mid-decade.
2. Needed repairs and alterations in shore facilities and operating practices for the receipt, storage, issue, and handling of petroleum products, to prevent leakage and accidental discharge to the environment.
3. Required repairs and alterations to naval ship systems, equipment, and procedures for storing and/or handling oily mixtures while underway to prevent discharge to the ocean environment.

For further references to pollution consult *Basic Military Requirements* NAVEDTRA 10054-C (Series).

APPENDIX I

THE METRIC SYSTEM

The metric system was developed by French scientists in 1790 and was specifically designed to be an easily used system of weights and measures to benefit science, industry, and commerce. The metric system is calculated entirely in powers of 10, so one need not work with the various mathematical bases used with the English system, such as 12 inches to a foot, 3 feet to a yard, and 5280 feet to a mile.

The system is based on the "meter" which is one ten-millionth of the distance from the Equator to the North Pole. It is possible to develop worldwide standards from this base of measurement. The metric system of weights is based on the gram, which is the weight of a specific quantity of water.

Soon after the system was developed scientists over the world adopted it and were able to deal with the mathematics of their experiments more easily. The data and particulars of their work could be understood by other scientists anywhere in the world. During the early 19th century many European nations adopted the new system for engineering and commerce. It was possible for these countries to trade manufactured goods with one another without worrying whether it would be possible to repair machinery from another country without also buying special wrenches and measuring tools. Countries could buy and sell machine tools and other sophisticated and precision machinery without troublesome modifications or alterations. It was much easier to teach the metric system, since meters can be changed to kilometers or centimeters with the movement of a decimal point, which is roughly like being able to convert yards to miles or inches by adding zeros and a decimal instead of multiplying by 1760 or dividing by 36.

With the exception of the United States, all the industrialized nations of the world have adopted the metric system. Even England and Canada are changing from their traditional systems of measure, and the metric system will be almost universal by 1980.

Although the metric system has not been officially legislated by the Congress, the metric system is becoming more prominent in this country. Most automobile mechanics own some metric wrenches to work on foreign cars or foreign components in American cars. Almost all photographic equipment is built to metric standards. Chemicals and drugs are usually sold in metric quantities, and "calorie counters" are using a metric unit of thermal energy.

Because we are allied with countries who use the metric system, much of our military information is in metric terms. Military maps use meters and kilometers instead of miles, and many weapons are in metric sizes, such as 7.62 mm, 20 mm, 40 mm, 75 mm, and 155 mm. Interchange of military equipment has caused a mixture of metric and English measure equipment since World War I when the army adopted the French 75 mm field gun, and World War II when the Navy procured the Swedish 40 mm Bofors and the Swiss 20 mm Oerlikon heavy machine guns.

It is inevitable that the United States will officially adopt the metric system. Exactly when this happens and how rapidly the changeover will depend on economics, since the expense of retooling our industry and commerce to new measurements will be very great. The cost of conversion will be offset by increased earnings from selling machinery and products overseas. Another benefit is that scientists use the metric system, but their calculations now have to be translated into English measure to be used by industry. With adoption of the metric system ideas can go directly from the drawing board to the assembly line.

The Navy will be using the metric system more during the next few years. Although you will find it easier to solve problems using this system, at first you will find it difficult to visualize or to estimate quantities in unfamiliar units of measure.

Fortunately, many metric units can be related to equivalent units in the English system.

The meter which is the basic unit is approximately one-tenth longer than a yard.

The basic unit of volume, the liter, is approximately one quart. The gram is the weight of a cubic centimeter, or milliliter, of pure water and is the basic unit of weight. As a common weight though, the kilogram, or kilo, which equals the weight of a liter of water, weighs 2.2 pounds. The cubic centimeter (cc) is used where we would use the square inch, and where we measure by the fluid ounce, the metric system employs the milliliter (ml). For power measure the metric system uses the kilowatt (kW), which is approximately 1.3 horsepower.

In terms of distance, a land mile is eight-fifths of a kilometer and a nautical mile is 1.852 kilometers, or nearly 2 kilometers.

A basic metric expression of pressure is the kilogram per square centimeter, which is 14.2 psi, nearly 1 atmosphere of pressure.

When working on foreign machinery, you may notice that your half-inch, three-quarter inch, and one-inch wrenches will fit many of the bolts. These sizes correspond to 13 mm, 19 mm, and 26 mm respectively in the metric system, and are very popular because they are interchangeable. The 13/16-inch spark plug wrench, which is standard in this country, is intended to fit a 20 mm nut.

The basic quantities of the metric system are multiplied or divided by powers of 10 to give other workable values. We cannot easily measure machine parts in terms of a meter, so the millimeter, or one-thousandth of a meter is used. For very fine measure the micron, also called the micrometer, can be used. It is one-millionth part of a meter, or one-thousandth of a millimeter. For small weights the milligram, one-thousandth of a gram is used. All of these multiples are expressed with standard prefixes taken from Latin:

micro = 1/1,000,000
milli = 1/1,000
centi = 1/100
*deci = 1/10
*deca = 10
*hecto = 100
kilo = 1,000
*myria = 10,000
mega = 1,000,000

* Rarely used

Over the next few years the metric system will become more used by the Navy as well as by the civilian world. You will find it easy to work with once you have mastered the basic terms. It will be difficult to translate values from our present system to the metric system, but this operation will become unnecessary once the new measurements are totally adopted.

Tables of equivalent English measure and metric equivalents are essential when you work simultaneously with both systems. The table which follows shows the equivalent measures of the two systems. The columns on the left have the equivalent values which are accurate enough for most work, and on the right are the multiples used to convert the values with a high degree of accuracy.

U.S. CUSTOMARY AND METRIC SYSTEM UNITS OF MEASUREMENTS

THESE PREFIXES MAY BE APPLIED TO ALL SI UNITS

Multiples and Submultiples	Prefixes	Symbols
1 000 000 000 000 = 10^{12}	tera (tĕr′ȧ)	T
1 000 000 000 = 10^{9}	giga (jĭ′gȧ)	G
1 000 000 = 10^{6}	mega (mĕg′ȧ)	M •
1 000 = 10^{3}	kilo (kĭl′ō)	k •
100 = 10^{2}	hecto (hĕk′tō̂)	h
10 = 10	deka (dĕk′ȧ)	da
0.1 = 10^{-1}	deci (dĕs′ĭ)	d
0.01 = 10^{-2}	centi (sĕn′tĭ)	c •
0.001 = 10^{-3}	milli (mĭl′ĭ)	m •
0.000 001 = 10^{-6}	micro (mī′krō̂)	μ •
0.000 000 001 = 10^{-9}	nano (năn′ō̂)	n
0.000 000 000 001 = 10^{-12}	pico (pē·kō̂)	p
0.000 000 000 000 001 = 10^{-15}	femto (fĕm′tō̂)	f
0.000 000 000 000 000 001 = 10^{-18}	atto (ăt′tō̂)	a

• MOST COMMONLY USED

ENGLISH AND METRIC SYSTEM UNITS OF MEASUREMENT

COMMON EQUIVALENTS AND CONVERSIONS

Approximate Common Equivalents		Conversions Accurate to Parts Per Million (units stated in abbreviated form)	
		Number X Factor	
1 inch	= 25 millimeters	in X 25.4*	= mm
1 foot	= 0.3 meter	ft X 0.3048*	= m
1 yard	= 0.9 meter	yd X 0.9144*	= m
1 mile†	= 1.6 kilometers	mi X 1.60934	= km
1 square inch	= 6.5 square centimeters	in^2 X 6.4516*	= cm^2
1 square foot	= 0.09 square meter	ft^2 X 0.0929030	= m^2
1 square yard	= 0.8 square meter	yd^2 X 0.836127	= m^2
1 acre	= 0.4 hectare	acres X 0.404686	= ha
1 cubic inch	= 16 cubic centimeters	in^3 X 16.3871	= cm^3
1 cubic foot	= 0.03 cubic meter	ft^3 X 0.0283168	= m^3
1 cubic yard	= 0.8 cubic meter	yd^3 X 0.764555	= m^3
1 quart (lq.)	= 1 liter	qt (lq.) X 0.946353	= l
1 gallon	= 0.004 cubic meter	gal X 0.00378541	= m^3
1 ounce (avdp)	= 28 grams	oz (avdp) X 28.3495	= g
1 pound (avdp)	= 0.45 kilogram	lb (avdp) X 0.453592	= kg
1 horsepower	= 0.75 kilowatt	hp X 0.745700	= kW
1 pound per square inch	= 0.07 kilogram per square centimeter	psi X 0.0703224	= kg/cm^2
1 millimeter	= 0.04 inch	mm X 0.0393701	= in
1 meter	= 3.3 feet	m X 3.28084	= ft
1 meter	= 1.1 yards	m X 1.09361	= yd
1 kilometer	= 0.6 mile	km X 0.621371	= mi
1 square centimeter	= 0.16 square inch	cm^2 X 0.155000	= in^2
1 square meter	= 11 square feet	m^2 X 10.7639	= ft^2
1 square meter	= 1.2 square yards	m^2 X 1.19599	= yd^2
1 hectare	= 2.5 acres	ha X 2.47105	= acres
1 cubic centimeter	= 0.06 cubic inch	cm^3 X 0.0610237	= in^3
1 cubic meter	= 35 cubic feet	m^3 X 35.3147	= ft^3
1 cubic meter	= 1.3 cubic yards	m^3 X 1.30795	= yd^3
1 liter	= 1 quart (lq.)	l X 1.05669	= qt (lq.)
1 cubic meter	= 250 gallons	m^3 X 264.172	= gal
1 gram	= 0.035 ounces (avdp)	g X 0.0352740	= oz (avdp)
1 kilogram	= 2.2 pounds (avdp)	kg X 2.20462	= lb (avdp)
1 kilowatt	= 1.3 horsepower	kW X 1.34102	= hp
1 kilogram per square centimeter	= 14.2 pounds per square inch	kg/cm^2 X 14.223226	= psi

†nautical mile = 1.852 kilometers

* exact

APPENDIX II

GLOSSARY

ABATEMENT. The act of reducing in degree or intensity.

ACCELERATOR. A pedal for regulating the speed of an engine.

ACCELERATOR PUMP. A small pump in the carburetor, operated by accelerator linkage, which supplies additional fuel when needed for acceleration of the vehicle.

ACRID. Sharp and harsh, or unpleasantly pungent in taste or odor.

ACRYLIC. A surface finish, made from synthetic polymers, which dries by solvent evaporation.

ADVANCEMENT. The action of being promoted to the next highest position in the chain of command.

ALIPHATIC NAPHTHA. A mixture of organic compounds and petroleum hydrocarbon mixtures.

AMPERE. Unit of measurement of the flow of electric current.

ANNULUS. An internal ring gear in the planetary gear system that operates in conjunction with a sun gear, pinion gears, and pinion carrier.

ANODIZE. To subject metal to electrolytic action, as the anode of a cell, in order to coat it with a protective film.

ANTIFRICTION BEARING. A bearing constructed with balls or rollers between the journal and bearing surfaces to provide a rolling action instead of sliding friction.

ANTIKNOCK. That property which opposes knocking in engine fuels.

ARBOR. A shaft for holding or mounting material for machine operations.

ATOMIZE. To reduce a liquid to minute particles or to a fine spray.

ATMOSPHERIC PRESSURE. The pressure of the atmosphere, or air, due to its weight pressing downward. Average is 14.7 psi at sea level.

AXLE. A crossbar supporting a vehicle on which one or more wheels turn.

AXLE RATIO. The ratio between the propeller shaft and rear-wheel rpm; gear reduction in the differential.

BACKFIRING. The pre-explosion of an air-fuel mixture so that the explosion passes the still-open intake valve and flashes back through the intake manifold.

BACKLASH. The clearance between meshing teeth of two gears, which will permit backward rotation of the driven gear in the opposite direction to the driving rotation.

BACK PRESSURE. A resistance to free flow, such as a restriction in the exhaust system.

BAFFLE. An obstruction for checking or deflecting the flow of gases or sound in a confined area.

BDC. Bottom dead center. The piston position when the piston has moved to the bottom of the cylinder and the center line of the connecting rod is parallel to the cylinder walls.

BRAKE HORSEPOWER. The power delivered by the engine which is available for driving the vehicle.

BRITISH THERMAL UNIT. Quantity of heat required to raise the temperature of one pound of water one degree F.

BURR. A featheredge of metal left on a part being cut with a cutting tool.

CALIPER. A measuring tool that can measure the thickness of a block, the diameter of a shaft, or the bore of a hold (inside caliper).

CAMSHAFT. The shaft in an engine that has a series of cams for operating the valve mechanisms. It is driven by gears or sprockets and chains from the crankshaft.

CARBON. A substance deposited on engine parts by the combustion of fuel. Carbon forms on pistons, rings, valves, etc., inhibiting their action.

CARBON DIOXIDE. A gas resulting from the burning of fuel. Compressed into solid form, this material is "dry ice" and remains at a temperature of -109 degrees F. It can change from a solid to a vapor and can be used as a refrigerant.

CARBON MONOXIDE. A poisonous gas produced by an operating gasoline engine. It is colorless, odorless, and can be fatal.

CARBURETOR. A device in a fuel system that mixes air and gasoline in proper proportions to produce a combustible gas.

CELSIUS. A scale of temperature measurement on which, under standard atmospheric pressure, water freezes at 0 degrees and boils at 100 degrees.

CHASSIS. The assembly of mechanisms that make up the major operating part of the vehicle.

CHOKE. In the carburetor, a device that chokes off the air flow through the air horn, thus producing a partial vacuum in the air horn for greater fuel delivery and a richer fuel-air mixture.

CLUTCH. The mechanism in the power train of a vehicle that connects the engine crankshaft to, or disconnects it from, the transmission and thus the remainder of the power train.

COHESION. A union between similar parts, or the process of sticking together tightly.

COMBUSTION. The rapid burning of the air-fuel mixture in the cylinder.

COMPRESSION. Denotes an increase of pressure on a fluid or spring by the use of mechanical energy.

COMPRESSOR. Energy-driven unit that circulates and pressurizes the refrigerant in an air-conditioner unit, or compresses air for an air-brake system.

CONDENSER. The device in an air conditioner to which vaporized refrigerant at high pressure is delivered. As it passes through the condenser, it removes heat from the surrounding air. Also an electrical device that stores electrical energy.

CONDUCTOR. A material along or through which electricity will flow with slight resistance to transport the electrical flow from one place to another.

COULOMB. The quantity of electricity transferred by an electric current of one ampere in one second.

COUNTERSHAFT. In the transmission, a shaft with gears that turns counter to the clutch shaft and is used to produce reverse motion.

CRANKSHAFT. The main shaft of the engine with piston rods attached that changes reciprocating motion into rotary action.

CROSS FIRING. The jumping of a high-voltage surge in the ignition secondary to the wrong high-tension lead so that the wrong spark plug fires. Usually caused by faulty insulation or a defective distributor cap or rotor.

CURRENT. The flow of electricity.

CYLINDER. A tubular structure in the engine in which the piston moves up and down.

DEHUMIDIFICATION. To remove moisture from the air in air-conditioned spaces.

DESICCANTS. A substance used to collect and hold moisture in a refrigerating system. A dry agent used in other systems to remove moisture.

DETONATION. The engine sound that indicates a too rapid burning of the fuel-air mixture in the cylinders.

DIESEL CYCLE. An engine cycle of events in which air alone is compressed and the fuel is injected near the end of the compression stroke.

DICHLORODIFLUROMETHANE. A refrigerant commonly known as R-12. Chemical formula is CCL_2F_2. Boiling point at atmospheric pressure is -21.62 F.

DIRECTIVES. An authoritative instrument issued by a high-level official body or competent official that serves to direct, guide, and usually impel toward an action, attainment, or goal.

DYNAMOMETER. A device for measuring the power produced by an internal combustion engine.

ELECTRODE. Refers to the insulated center rod and rod attached to the shell of the spark plug. Also a welding rod.

EMULSION. A milk-like viscuous mixture of two liquids.

END PLAY. The amount of end play movement of the crankshaft.

ENERGY. The ability or capacity to do work.

EVAPORATOR COIL. A device made of a coil of tubing which functions as a refrigerant evaporator.

EXPANSION VALVE. A valve between the condenser and the evaporator and located at the evaporator. It provides a pressure differential; the high pressure on the condenser side is reduced to low pressure on the evaporator side.

FOUR-STROKE CYCLE. The four operations of intake, compression, power, and exhaust piston strokes that make up the complete cycle of events in the four-stroke cycle engine.

FREEZE PLUG. A disc or cup-shaped metal device inserted in a hole in a casting. Used in the engine block to prevent the coolant from freezing and cracking the block. Also known as an expansion plug.

FUSIBLE PLUG. A plug or fitting made with a metal of a known low melting temperature; used as a safety device to release pressures in case of fire.

GAS. Vapor phase or state of a substance.

GASKET. A cutout or perforated sheet of metal, cork, or other material designed to provide a tight seal between two assembled parts of an engine, transmission, or differential.

GEAR RATIO. The relative speeds at which two gears or shafts turn; the proportional rate of rotation.

GEARS. Mechanical devices to transmit power or turning effort from one shaft to another; gears contain teeth that interlace or mesh as the gears turn.

GOVERNOR. A device to control and regulate speed. May be mechanical, hydraulic, or electrical.

HARMONIC BALANCER. A device designed to reduce torsional or twisting vibration which occurs along the length of the crankshaft and is used in multiple cylinder engines.

HORSEPOWER. A measure of a definite amount of power; 33,000 ft-lb of work per minute.

HYDRAULIC VALVE LIFTER. A valve lifter that, by means of hydraulic oil pressure, maintains zero valve clearance so that valve noise is reduced.

HYDROMETER. An instrument for determining the state of charge in a battery by measuring the specific gravity of the electrolyte.

IGNITION. A means to ignite fuel to develop power in the cylinder of an engine.

INHIBITOR. A material to restrain or hinder some unwanted action.

INJECTOR. A pump-type action that injects or inserts fuel against pressure into a cylinder or chamber, usually of a diesel engine.

KNOCK. A rapping or hammering noise in an engine resulting from an excessively rapid burning of the compressed fuel.

LAPPING. The process of fitting one surface to another by rubbing them together with an abrasive between the two surfaces. Used in fitting valves to valve seats.

LIQUID RECEIVER. A cylinder connected to a condenser outlet for the storage of a liquid in a system.

LOUVER. Openings or vents in the hood or body; used for ventilation.

LOW SIDE PRESSURE. Pressure in the cooling side of an air-conditioner cycle.

MAINTENANCE. The art of keeping ground support equipment in a ready condition or of correcting malfunctions in equipment.

MICROMETER. A measuring device that accurately measures such dimensions as shaft or bore diameter or thickness of an object.

MONOCHLORODIFLUOROMETHANE. A refrigerant better known as R-22; chemical formula is $CHClF_2$.

NEEDLE BEARING. An antifriction bearing which uses a great number of rollers of small diameter in relation to their length.

NEUTRON. That portion of an atom which carries no electrical charge.

OCTANE. A measure of the anti-knock property of gasoline. The higher the octane rating, the more resistant the gasoline is to knocking.

PISTON. The cylindrical part that moves up and down in the cylinder of an engine.

PISTON SKIRT. The lower part of the piston.

PISTON SLAP. The hollow, bell-like sound made by an excessively loose piston slapping against the cylinder walls.

PITMAN ARM. The part of the steering gear that is linked to the steering knuckle arms of the wheels and swings back and forth for steering.

POWER STEERING. A hydraulic cylinder on the steering system of a vehicle that multiplies the driver's effort as he turns the steering wheel so that the physical effort is reduced.

POWER STROKE. The piston stroke from TDC to BDC, during which the air-fuel mixture burns and forces the piston down so that the engine produces power.

PSI. Pounds per square inch; a measure of pressure.

RATIO. The relation or proportion that one number bears to another.

RECIPROCATING. A back and forth movement.

REFRIGERANT. A substance used in an air-conditioning system which absorbs and gives up heat as it changes from a liquid to a gas to a liquid.

RING GAP. The gap between the ends of the piston ring with the ring in place on the piston.

RPM. Revolutions per minute–usually refers to the speed of the driveshaft.

SAFETY. The act of being safe from undergoing or causing hurt, injury, or loss.

SHIM. A strip of copper or similar material used under a bearing cap; for example, to increase bearing clearance.

SHOCK ABSORBER. A device that hydraulically or by springs checks the rapid or excessive movement between two parts.

SOLENOID. An electromagnet with a movable core that acts as a valve or relay.

STROBOSCOPE. An electrical testing device used in checking ignition system components.

TDC. Opposite of BDC; a piston at the top of its travel.

TETRAETHYLLEAD. A chemical put into engine fuel which increases octane rating or reduces knock tendency.

THERMAL EXPANSION VALVE. A control valve operated by temperature and pressure within the evaporator coil which controls the flow of refrigerant.

THERMOCOUPLE. A device which generates its own electricity by using two dissimilar metals that are welded together and when the junction is heated a voltage is generated.

THERMOSTAT. A device that is operated by temperature changes to control the flow of coolant through an engine.

THROW OUT BEARING. The bearing in the clutch that can be moved into the release levers by the clutch-pedal action so as to cause a disconnection between the engine crankshaft and power train.

TIE RODS. The rods in the steering system that link the pitman arm to the steering knuckle arms.

TORQUE. Turning or twisting effort measured in pound-feet or foot-pounds.

TRANSMISSION. The device in the power train that provides different gear ratios between the engine and rear wheels, in drive as well as in reverse.

TURBINE. A series of blades on a wheel situated at an angle to the shaft against which fluids or gases are impelled to impart rotary motion to the shaft.

TURBULENCE. The state of being violently disturbed. In an engine, the rapid swirling motion imparted to the air-fuel mixture entering the cylinders.

TWO-STROKE CYCLE. The series of events taking place in an engine where intake, compression, power, and exhaust take place in two piston strokes.

VACUUM. The absence of air or other substance.

VALVE. A device that can be opened or closed to allow or stop the flow of a liquid, gas, or vapor from one place to another, or change its direction.

VENTURI. A tube having a constriction in the section forming the throat. As the velocity of flow of a fluid increases in the throat, the pressure decreases. It is used to meter the flow of gasoline in a carburetor. The amount of air flowing through the venturi determines the correct amount of fuel in the fuel-air mixture entering the cylinders.

VISCOSITY. The term used to describe a liquid's resistance to flow. A thick oil has greater viscosity than a thin oil.

VOLATILITY. A measurement of the ease with which a liquid vaporizes.

VORTEX. A whirling movement of a mass of liquid or air.

WOODRUFF KEY. A device used to align and hold a flywheel, pulley, or other rotating mechanism on a shaft; often half moon in shape.

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QUALIFICATIONS FOR ADVANCEMENT

This appendix provides you with a list of the minimum qualifications for advancement to Aviation Support Equipment Technician M Third and Second Class. The official source of this list is the Manual of Qualifications For Advancement, NAVPERS 18068-C, 1971. The assignment numbers given opposite the qualifications refer to the assignments in the NRCC, Aviation Support Equipment Technician M 3 & 2, NAVEDTRA 10315-B. Each course assignment contains information related to a practical or knowledge factor, as shown.

AVIATION SUPPORT EQUIPMENT TECHNICIAN M (Mechanical) - ASM

Aviation Support Equipment Technicians (M) service, test, and perform organizational and intermediate level maintenance and repair of gasoline and diesel engines in mobile and self-propelled aviation support equipment and associated automotive systems, including fuel systems, automatic and power, transmissions, differentials, and steering systems; maintain gas turbine compressor units and air-conditioning systems used in servicing aircraft; maintain and operate gas turbine compressor unit test stands; and perform periodic maintenance inspections of aviation support equipment.

QUALIFICATIONS FOR ADVANCEMENT	Required for Advancement to ASM	ASSIGNMENT
A. SAFETY		
1.00 Practical Factors		
.01 Observe safety precautions in the handling, servicing, and maintenance of aviation support equipment and in the use of related tools, equipment, and material . . .	E-4	1, 2, 6, 9, 10, 11, 12, 13, 14
.02 Observe safety precautions applicable to:		
a. Electrical work, particularly those related to energized electrical circuits, handling electrolyte, batteries, short circuits, and grounding.	E-4	7
b. Mechanical work, particularly those related to internal combustion engines, power tools, and fuels and oils.	E-4	6, 11
B. MAINTENANCE		
1.00 Practical Factors		
.01 Prepare Maintenance Data Collection forms: CCF's, UR's, MAF's, SAF's, TDC's, and MHA cards	E-4	100% OPNAVINST 4790.2A
.02 Make entries on support equipment forms	E-4	100% OPNAVINST 4790.2A

QUALIFICATIONS FOR ADVANCEMENT (Continued)

B. MAINTENANCE (Continued)

		Required for Advancement to	
		ASM	ASSIGNMENT
1.00	Practical Factors (Continued)		
.03	Service and operate aviation support equipment	E-4	3
.04	Perform daily maintenance inspections and service equipment.	E-4	3, 8, 9, 11, 12, 13
.05	Perform periodic maintenance inspections	E-4	7, 8, 9, 10, 12, 13
.06	Replace seals and packings	E-4	7, 11
.07	Perform periodic maintenance on aviation ordnance handling equipment	E-4	2
.40	Perform systems operational test; verify discrepancies	E-5	6, 7, 8, 9, 10, 12, 13
2.00	Knowledge Factors		
.01	Elementary physics of heat, light, sound, fluids, gases, and electricity.	E-4	3, 4
.02	Types and purposes of Maintenance and Material Management	E-4	100% OPNAVINST 4790.2A
.03	Types, uses, and care of common aircraft handling equipment.	E-4	2, 3
.04	Types and designations of fuel, hydraulic fluids, coolants, and lubricants	E-4	6, 11
.40	Procedures for incorporating equipment modifications and changes.	E-5	7

C. ENGINES AND MECHANICAL SYSTEMS

		ASM	ASSIGNMENT
1.00	Practical Factors		
.01	Service and adjust steering systems.	E-4	9
.02	Adjust, repair and replace carburetors	E-4	8
.03	Make minor engine tune-ups	E-4	8, 9
.04	Adjust and make minor repairs to gasoline and diesel engines.	E-4	8, 9
.05	Remove and replace cooling system components, including pumps, radiators, hoses, thermostats, and shutters	E-4	6
.06	Service, maintain, and make minor repairs and adjustments to gasoline and diesel fuel systems.	E-4	8, 9
.07	Service and adjust transmissions, clutches, and connecting linkages.	E-4	10, 11
.08	Remove, repair and replace fuel system components, including pumps, filters, injectors, and valves.	E-4	8, 9
.40	Inspect, adjust, and test run gas turbine compressor units.	E-5	12
.42	Remove, install, and make adjustments to fuel controls of gas turbine compressor units	E-5	12
.43	Test, adjust, repair, and replace governors.	E-5	7
.44	Remove and replace clutches.	E-5	10

QUALIFICATIONS FOR ADVANCEMENT (Continued)

C. ENGINES AND MECHANICAL SYSTEMS (Continued)

1.00 Practical Factors (Continued)

		Required for Advancement to	
		ASM	ASSIGNMENT
.45	Remove and replace rings, bearings, wrist pins, and pistons	E-5	6
.46	Grind and adjust valves	E-5	6
.48	Make repairs to transmissions and differentials	E-5	10
.49	Make major engine tune-ups	E-5	8, 9, 12
.50	Identify malfunctioning components of internal combustion engines	E-5	2, 6, 7, 8, 9
.51	Inspect compressors and turbines for axial and radial clearances	E-5	12

2.00 Knowledge Factors

		ASM	ASSIGNMENT
.01	Effects of temperature, pressure, and other variables on engine performance	E-4	6, 8, 9, 11, 12
.02	Procedures for bleeding fuel systems	E-4	8, 11
.03	Procedures for internal and external cleaning of gas turbine compressor units	E-4	12
.04	Principles of power transmission systems	E-4	10
.05	Functions of components of power train, suspension, and steering systems	E-4	9
.06	Principles of gasoline and diesel engines	E-4	5, 6, 7, 8, 9
.07	Principles of internal combustion fuel systems	E-4	7, 8, 9
.09	Effects of electrical load conditions on engine governor settings	E-4	7
.40	Procedures for steering and front end alinement	E-5	9
.41	Principles of hydraulic clutches, fluid couplings, and power steering	E-5	9, 10
.42	Functions and interrelationships of components of gasoline, diesel, and gas turbine engines	E-5	6, 7, 8, 12

D. STRUCTURES

1.00 Practical Factors

		ASM	ASSIGNMENT
.02	Use oxyacetylene torches to weld and cut metal	E-4	9
.05	Service, maintain, and make minor repairs to chassis and frames	E-4	9, 11
.46	Perform and interpret results of dye penetrant inspections	E-5	6

2.00 Knowledge Factors

		ASM	ASSIGNMENT
.01	Types and applications of corrosion prevention, preservation and moisture protecting materials	E-4	13, 14
.02	Procedures for preserving and depreserving aviation support equipment and accessories	E-4	13, 14

QUALIFICATIONS FOR ADVANCEMENT (Continued)

		Required for Advancement to	
		ASM	ASSIGNMENT
E.	HYDRAULICS AND PNEUMATICS		
1.00	Practical Factors		
.04	Fabricate and fit rigid tubing and low pressure flexible hose assemblies	E-4	13
2.00	Knowledge Factors		
.01	Units of measure and terms associated with hydraulics and pneumatics	E-4	3, 10
F.	POWER GENERATING SYSTEMS		
2.00	Knowledge Factors		
.02	Theory of a.c. and d.c. electricity and principles of magnetism	E-4	4
.03	Principles of electro-magnetic induction	E-4	4
G.	AUTOMOTIVE ELECTRICAL SYSTEMS		
1.00	Practical Factors		
.01	Repair, remove and install components of ignition and starting systems	E-4	7, 9
2.00	Knowledge Factors		
.01	Electrical terms and units of measure.	E-4	4
.04	Principles of ignition systems and automotive electrical systems.	E-4	6, 7, 8
.40	Functions and interrelationships of components of automotive electrical systems.	E-5	6, 7, 8
H.	REFRIGERATION AND AIR-CONDITIONING SYSTEMS		
1.00	Practical Factors		
.02	Perform routine tests for locating leaks of refrigerant in refrigeration and air-conditioning equipment.	E-4	13
.03	Repair and replace mechanical components of air-conditioning systems	E-4	13
.40	Adjust thermal expansion valve, high-pressure and low-pressure switches, thermostats, cooling water regulator, and reducing valve.	E-5	13
.41	Check for non-condensable gases and pump down refrigerant systems.	E-5	13
.42	Adjust temperature and pressure control units.	E-5	13
.43	Identify malfunctioning mechanical components of air-conditioning systems	E-5	13
.45	Dehydrate, test, and recharge refrigeration and air-conditioning systems	E-5	13

QUALIFICATIONS FOR ADVANCEMENT (Continued)

		Required for Advancement to ASM	ASSIGNMENT
H.	REFRIGERATION AND AIR-CONDITIONING SYSTEMS		
2.00	Knowledge Factors		
.01	Principles of air-conditioning systems	E-4	12
.02	Function of electrical components and controls of air-conditioning	E-4	12, 13
.03	Function of mechanical components of air-conditioning systems	E-4	12, 13
.04	Construction and operation of flight line and field service type of refrigerating units and characteristics of refrigerants	E-4	13
.40	Purpose of refrigeration expansion valves	E-5	12, 13
.42	Principles of mechanical components and controls of air-conditioning systems	E-5	13
.43	Functions and interrelationships of electrical components of air-conditioning systems	E-5	13
.44	Functions and interrelationships of mechanical components of air-conditioning systems	E-5	13
.45	Lubricant requirements and precautions when handling dehydrated oils for refrigerant systems	E-5	13
I.	TOOLS AND TEST EQUIPMENT		
1.00	Practical Factors		
.01	Use chain hoists and jacks to service and repair equipment	E-4	2
.05	Select, use, and care for common handtools	E-4	1, 2
.40	Maintain and operate gas turbine compressor unit test stands	E-5	12
2.00	Knowledge Factors		
.01	Uses and applications of micrometers, inside-outside calipers, feeler gages, and dial indicators	E-4	1
.02	Characteristics of basic electrical measuring instruments	E-4	1, 4
.05	Functions and applications of automotive engine analyzers	E-4	1, 8
J.	PUBLICATIONS AND DRAWINGS		
1.00	Practical Factors		
.01	Use pictorial diagrams, schematics, and charts in maintaining and servicing equipment	E-4	5
.02	Use maintenance instructions to locate and identify components of equipment	E-4	5
.40	Use publication indexes to identify and locate technical publications, directives, and manuals	E-5	5

QUALIFICATIONS FOR ADVANCEMENT (Continued)

		Required for Advancement to	
		ASM	ASSIGNMENT
J.	PUBLICATIONS AND DRAWINGS (Continued)		
2.00	Knowledge Factors		
.01	Standard symbols utilized in diagrams, drawings, chematics, charts, and prints.	E-4	5
.02	Military specifications for identification, marking, and color coding of electrical conductors and lines carrying fluids or gases	E-4	5
.03	Types of information contained in manuals relating to operation, servicing, inspection, and maintenance . .	E-4	5
Z.	ADMINISTRATION		
1.00	Practical Factors		
.40	Maintain current shop files of technical publications and directives	E-5	4
.41	Use publications relating to inspection, servicing, and maintenance of aviation ordnance handling equipment. . .	E-5	4
2.00	Knowledge Factors		
.39	Principles of the Maintenance Material Management (3M) System:		
	a. Planned Maintenance Subsystem (PMS).	E-4	100% OPNAVINST 4790.2A
	b. Maintenance Data Collection Subsystem (MDCS)	E-4	100% OPNAVINST 4790.2A
	c. Management by Exception.	E-5	100% OPNAVINST 4790.2A
.391	Elements of the Planned Maintenance Subsystem:		
	a. Types of maintenance inspections	E-4	100% OPNAVINST 4790.2A
	b. Types and uses of Maintenance Requirement Cards (MRC).	E-4	100% OPNAVINST 4790.2A
.392	Principles of Manhour Accounting:		
	a. Methods of Manhour Accounting (MHA).	E-4	100% OPNAVINST 4790.2A
	b. Purpose of Manhour Accounting.	E-4	100% OPNAVINST 4790.2A
.393	Functions of Maintenance Departments:		
	a. Levels of maintenance.	E-4	100% OPNAVINST 4790.2A
	b. Purpose of Visual Information Display System (VIDS)	E-4	100% OPNAVINST 4790.2A
	c. Material Control responsibilities.	E-5	100% OPNAVINST 4790.2A
	d. Types of maintenance instructions.	E-5	100% OPNAVINST 4790.2A
	e. Responsibilities of the Quality Assurance Division .	E-5	100% OPNAVINST 4790.2A

QUALIFICATIONS FOR ADVANCEMENT (Continued)

	Required for Advancement to	
Z. ADMINISTRATION (Continued)	ASM	ASSIGNMENT
2.00 Knowledge Factors (Continued)		
.393 Functions of Maintenance Departments (Continued)		
f. Unsatisfactory Material/Condition Reporting Program and information flow for Unsatisfactory Reports (UR)	E-5	100% OPNAVINST 4790.2A
.59 Functions of the Maintenance Data Collection Subsystem:		
a. Source documents used for data reporting	E-5	100% OPNAVINST 4790.2A
.591 Elements of Material Control:		
a. Purpose of the Supply Support Center	E-5	100% OPNAVINST 4790.2A
BB. ENVIRONMENTAL POLLUTION CONTROL		
1.00 Practical Factors		
None		
2.00 Knowledge Factors		
.01 Effect of incomplete combustion of fuels on air pollution	E-4	14
.02 Fuel components and combustion products which adversely affect air	E-4	14
.03 Means of controlling air pollution caused by fuel combustion	E-4	14
.04 Possible pollution threats due to oil and other fuel product spillage on the water or ground	E-4	14
.05 Procedures for limiting or minimizing the adverse effects of oil and fuel spillage	E-4	14

AVIATION SUPPORT EQUIPMENT TECHNICIAN M 3 & 2

NAVEDTRA 10315-B

Prepared by the Naval Education and Training Program Development
Center, Pensacola, Florida

Your NRCC contains a set of assignments and self-scoring answer sheets (packaged separately). The Rate Training Manual, Aviation Support Equipment Technician M 3&2, NAVEDTRA 10315-B, is your textbook for the NRCC. If an errata sheet comes with the NRCC, make all indicated changes or corrections. Do not change or correct the textbook or assignments in any other way.

HOW TO COMPLETE THIS COURSE SUCCESSFULLY

Study the textbook pages given at the beginning of each assignment before trying to answer the items. Pay attention to tables and illustrations as they contain a lot of information. Making your own drawings can help you understand the subject matter. Also, read the learning objectives that precede the sets of items. The learning objectives and items are based on the subject matter or study material in the textbook. The objectives tell you what you should be able to do by studying assigned textual material and answering the items.

At this point you should be ready to answer the items in the assignment. Read each item carefully. Select the BEST ANSWER for each item, consulting your textbook when necessary. Be sure to select the BEST ANSWER from the subject matter in the textbook. You may discuss difficult points in the course with others. However, the answer you select must be your own. Use only the self-scoring answer sheet designated for your assignment. Follow the scoring directions given on the answer sheet itself and elsewhere in this course.

Your NRCC will be administered by your command or, in the case of small commands, by the Naval Education and Training Program Development Center. No matter who administers your course you can complete it successfully by earning grades that average 3.2 or higher. If you are on active duty, the average of your grades in all assignments must be at least 3.2. If you are NOT on active duty, the average of your grades in all assignments of each creditable unit must be at least 3.2. The unit breakdown of the course, if any, is shown later under Naval Reserve Retirement Credit.

WHEN YOUR COURSE IS ADMINISTERED BY LOCAL COMMAND

As soon as you have finished an assignment, submit the completed self-scoring answer sheet to the officer designated to administer it. He will check the accuracy of your score and discuss with you the items that you do not understand. You may wish to record your score on the assignment itself since the self-scoring answer sheet is not returned.

If you are completing this NRCC to become eligible to take the fleet wide advancement examination, follow a schedule that will enable you to complete all assignments in time. Your schedule should call for the completion of at least one assignment per month.

Although you complete the course successfully, the Naval Education and Training Program Development Center will not issue you a letter of satisfactory completion. Your command will make a note in your service record, giving you credit for your work.

WHEN YOUR COURSE IS ADMINISTERED BY THE NAVAL EDUCATION AND TRAINING PROGRAM DEVELOPMENT CENTER

After finishing an assignment, go on to the next. Retain each completed self-scoring answer sheet until you finish all the assignments in a unit (or in the course if it is not divided into units). Using the envelopes provided, mail your self-scored answer sheets to the Naval Education and Training Program Development Center where the scores will be verified and recorded. Make sure all blanks at the top of each answer sheet are filled in. Unless you furnish all the information required, it will be impossible to give you credit for your work. You may wish to record your scores on the assignments since the self-scoring answer sheets are not returned.

The Naval Education and Training Program Development Center will issue a letter of satisfactory completion to certify successful completion of the course (or a creditable unit of the course). To receive a course-completion letter, follow the directions given on the course-completion form in the back of this NRCC.

You may keep the textbook and assignments for this course. Return them only in the event you disenroll from the course or otherwise fail to complete the course. Directions for returning the textbook and assignments are given on the book-return form in the back of this NRCC.

PREPARING FOR YOUR ADVANCEMENT EXAMINATION

Your examination for advancement is based on the Manual of Qualifications for Advancement (NAVPERS 18068). The sources of questions in this examination are given in the Bibliography for Advancement Study (NAVEDTRA 10052). Since your NRCC and textbook are among the sources listed in this bibliography, be sure to study both in preparing to take your advancement examination. The qualifications for your rating may have changed since your course and textbook were printed, so refer to the latest editions of NAVPERS 18068 and NAVEDTRA 10052.

NAVAL RESERVE RETIREMENT CREDIT

This course is evaluated at 21 Naval Reserve retirement points, which will be credited in units as follows: Unit 1: 12 points upon satisfactory completion of Assignments 1 through 8; and, Unit 2: 9 points upon satisfactory completion of Assignments 9 through 14. These points are creditable to personnel eligible to receive them under current directives governing retirement of Naval Reserve personnel. Naval Reserve retirement credit will not be given for this course if the student has previously received retirement credit for an Aviation Support Equipment Technician M 3 & 2, NRCC or ECC.

COURSE OBJECTIVE

While completing this course you will demonstrate your understanding of course material by correctly answering items on the following; the ASM rating structure, requirements, procedures, and sources of information to assist you in preparing for advancement; operation and maintenance of Aviation ground support equipment; operating principles and maintenance of gasoline and diesel engines and associated systems; operating principles and maintenance of gas turbine compressors; operating principles and maintenance of ground air conditioners; use of publications relating to the ASM rating; corrosion control; and enviromental pollution control.

While working on this nonresident career course, you may refer freely to the text. You may seek advice and instruction from others on problems arising in the course, but the solutions submitted must be the result of your own work and decisions. You are prohibited from referring to or copying the solutions of others, or giving completed solutions to anyone else taking the same course.

Naval nonresident career courses may include a variety of items -- multiple-choice, true-false, matching, etc. The items are not grouped by type; regardless of type, they are presented in the same general sequence as the textbook material upon which they are based. This presentation is designed to preserve continuity of thought, permitting step-by-step development of ideas. Some courses use many types of items, others only a few. The student can readily identify the type of each item (and the action required of him) through inspection of the samples given below.

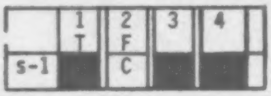
MULTIPLE-CHOICE ITEMS

Each item contains several alternatives, one of which provides the best answer to the item. Select the best alternative and erase the appropriate box on the answer sheet.

SAMPLE

s-1. The first person to be appointed Secretary of Defense under the National Security Act of 1947 was
  1. George Marshall
  2. James Forrestal
  3. Chester Nimitz
  4. William Halsey

The erasure of a correct answer is indicated in this way on the answer sheet:



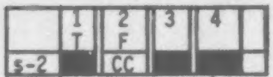
TRUE-FALSE ITEMS

Determine if the statement is true or false. If any part of the statement is false the statement is to be considered false. Erase the appropriate box on the answer sheet as indicated below.

SAMPLE

s-2. Any naval officer is authorized to correspond officially with a bureau of the Navy Department without his commanding officer's endorsement.

The erasure of a correct answer is also indicated in this way on the answer sheet:



MATCHING ITEMS

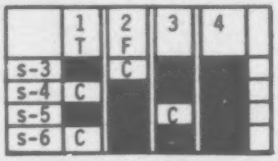
Each set of items consists of two columns, each listing words, phrases or sentences. The task is to select the item in column B which is the best match for the item in column A that is being considered. Specific instructions are given with each set of items. Select the numbers identifying the answers and erase the appropriate boxes on the answer sheet.

SAMPLE

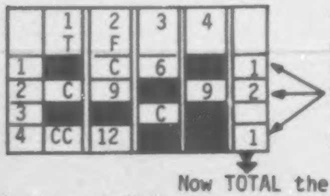
In items s-3 through s-6, match the name of the shipboard officer in column A by selecting from column B the name of the department in which the officer functions.

A. Officers	B. Departments
s-3. Damage Control Assistant	1. Operations Department
s-4. CIC Officer	2. Engineering Department
s-5. Assistant for Disbursing	3. Supply Department
s-6. Communications Officer	

The erasure of a correct answer is indicated in this way on the answer sheet:



How To Score Your Immediate Knowledge of Results (IKOR) Answer Sheets



Total the number of incorrect erasures (those that show page numbers) for each item and place in the blank space at the end of each item.

Sample only

Number of boxes erased incorrectly	0-2	3-7	8-
Your score	4.0	[✓ 3.9]	3.8

Now TOTAL the column(s) of incorrect erasures and find your score in the Table at the bottom of EACH answer sheet.

NOTICE: If, on erasing, a page number appears, review text (starting on that page) and erase again until "C", "CC", or "CCC" appears. For courses administered by the Center, the maximum number of points (or incorrect erasures) will be deducted from each item which does NOT have a "C", "CC", or "CCC" uncovered (i.e., 3 pts. for four choice items, 2 pts. for three choice items, and 1 pt. for T/F items).

Assignment 1

Aviation Support Equipment Technician M Rating, Tools, and Lifting Devices

Text: Pages 1 - 42

In this course you will demonstrate that learning has taken place by correctly answering training items. The mere physical act of indicating a choice on an answer sheet is not in itself important; it is the mental achievement, in whatever form it may take, prior to the physical act that is important and toward which nonresident career course learning objectives are directed. The selection of the correct choice for a course training item indicates that you have fulfilled, at least in part, the stated objective(s).

The accomplishment of certain objectives, for example, a physical act such as drafting a memo, cannot readily be determined by means of objective type course items; however, you can demonstrate by means of answers to training items that you have acquired the requisite knowledge to perform the physical act. The accomplishment of certain other learning objectives, for example, the mental acts of comparing, recognizing, evaluating, choosing, selecting, etc., may be readily demonstrated in a course by indicating the correct answers to training items.

The comprehensive objective for this course has already been given. It states the purpose of the course in terms of what you will be able to do as you complete the course.

The detailed objectives in each assignment state what you should accomplish as you progress through the course. They may appear singly or in clusters of closely related objectives, as appropriate; they are followed by items which will enable you to indicate your accomplishment.

All objectives in this course are learning objectives and items are teaching items. They point out important things, they assist in learning, and they should enable you to do a better job for the Navy.

This self-study course is only one part of the total Navy training program; by its very nature it can take you only part of the way to a training goal. Practical experience, schools, selected reading, and the desire to accomplish are also necessary to round out a fully meaningful training program.

Learning Objective: Identify the general contents of chapter 1 of the text, and distinguish between general and service ratings, and between the terms rate and ratings.

1-1. In what manual are the minimum professional qualifications for advancement in all ratings listed?
1. NAVPERS 10056-D
2. NAVPERS 18068 (Series)
3. NAVEDTRA 10052-W
4. NAVEDTRA 10315-B

1-2. A general rating is one which reflects qualifications in
1. civilian skills identified with a peacetime Navy
2. civilian skills identified with a wartime Navy
3. broad occupational fields of related duties and functions
4. subdivisions or specialties within broad occupational fields

1-3. The rating structure for naval enlisted personnel in the AS rating provides for
1. service ratings only
2. general ratings only
3. both general and service ratings
4. general, service, and emergency ratings

1-4. Which term identifies personnel occupationally by pay grades?
1. Rate
2. Rating
3. Assignment
4. Billet

1-5. Which of the following rates is a service rate?
1. ASM2
2. AS1
3. ASCS
4. ASCM

1-6. Refer to figure 1-1 in your textbook. At what rate level does the AS have his first opportunity to apply for advancement to Warrant Officer (W-1)?
1. Second class
2. First class
3. Chief petty officer
4. Master chief petty officer

1-7. The ASM is NOT required to perform maintenance or service on which of the following types of aviation support equipment?
1. Gasoline and diesel engines in self-propelled equipment and associated automotive systems
2. Gas turbine compressor units and air-conditioning systems used in servicing aircraft
3. Gas turbine compressor unit test stands
4. AHT-63 hydraulic test stands

1-8. The specific duties which you will perform at your assigned activity will depend largely upon the
1. Navy schooling you have experienced
2. number of ASMs assigned to your activity
3. type of activity to which you are assigned
4. type and number of correspondence courses you have completed

1-9. Personnel anticipating transfer to a new activity and desiring information on duty preferences should consult which of the following publications?
1. The Enlisted Transfer Manual, NAVPERS 15909 (Series)
2. NAVEDTRA 10052 (Series)
3. The Manual of Qualifications for Advancement, NAVPERS 18068 (Series)
4. The Record of Practical Factors, NAVEDTRA 1414/1

Learning Objective: Indicate principles of good leadership and the relationship of leadership to advancement.

1-10. As an AS advances, his success is judged increasingly in terms of the
1. amount of work he does
2. amount of efficient work his men do
3. number of different billets he has filled
4. neatness and orderliness of the work areas for which he is responsible

1-11. Which of the following publications should the ASM striker study in order to learn the leadership qualities expected of him when he advances to a petty officer rate?
1. Aviation Support Equipment Technician M 3 & 2, NAVEDTRA 10315-B
2. Bibliography for Advancement Study, NAVEDTRA 10052 (Series)
3. Military Requirements for Petty Officer 3 & 2, NAVEDTRA 10056 (Series)
4. List of Training Manuals and Correspondence Courses, NAVEDTRA 10061 (Series)

Learning Objective: Recognize advantages of, procedures for, and materials to be studied in preparing for advancement.

1-12. In addition to receiving an increased amount of pay, the personal benefits realized from an advancement should include
1. a feeling of accomplishment only
2. greater interest in the jobs to be done only
3. increased respect from both supervisors and subordinates only
4. a feeling of accomplishment, greater interest in the jobs to be done, and increased respect from both supervisors and subordinates

1-13. The professional requirements for the ASM3 and ASM2 rates are given in the Manual of Qualifications for Advancerent ("Quals" Manual), NAVPERS 18068 (Series), as
1. knowledge factors and examination subjects
2. examination subjects and military factors
3. occupational standards
4. practical factors and military factors

1-14. The Record of Practical Factors, NAVPERS 1414/1, forms a part of each ASM's service record and provides a record of his
1. general performance on the job
2. grades of examinations required for advancement
3. demonstration of skills required for advancement
4. military qualifications in relation to other men in his rating

1-15. Which of the following actions should an ASM take when he is transferred from one activity to another?
1. Request a statement concerning his qualifications from the activity he is leaving
2. Secure his NAVPERS 1414/1 and take it to his new commanding officer
3. Inform his new division chief that he has completed his practical factors
4. Ensure that his NAVPERS 1414/1 is in his service record

1-16. The knowledge and skills required of a particular rating concerning a SPECIFIC weapons system are analyzed in the
1. applicable Rate Training Manual
2. Personnel Qualifications Standards (PQS)
3. Manual of Qualifications for Advancement
4. Record of Practical Factors

1-17. Guidelines for self-study of fundamentals normally taught in Preparatory, Fundamental, and Class-A schools are outlined in the PQS section entitled
1. Theory--100 Series
2. Systems--200 Series
3. Watch stations--300 Series
4. Qualification cards--400 Series

1-18. Which section of the Personnel Qualification Standards contains items designed to determine if an individual has the abilities necessary to perform maintenance on a system?
1. 100 Series--Theory
2. 200 Series--Systems
3. 300 Series--Watch stations
4. 400 Series--Qualification cards

1-19. What does a letter following the NAVEDTRA number assigned to the Bibliography for Advancement Study, NAVEDTRA 10052 (Series), indicate?
1. The BUPERS Notice that supercedes the publication
2. A revision to the publication
3. A supplement to the publication
4. The effective date of the publication

1-20. Before being eligible to take the Navy-wide advancement examination for a rate, the AS must complete those training manuals marked with an asterisk (*) in which publication?
1. The "Quals" Manual
2. List of Training Manuals and Correspondence Courses, NAVEDTRA 10061 (Series)
3. Training Publications for Advancement, NAVEDTRA 10052 (Series)
4. Manual of Enlisted Classifications, NAVPERS 15106 (Series)

1-21. Your textbook states that you should study the references which are recommended as well as those that are mandatory in the study bibliography in NAVEDTRA 10052 because
1. completion of those courses is necessary for being recommended for the next rate
2. those references may furnish source material for some questions in the written examination for advancement
3. you cannot be advanced without being examined on those references
4. those references are for your knowledge only and are not to be used for advancement items

1-22. The general qualifications which all enlisted personnel are expected to demonstrate as a minimum for advancement at all rate levels are
1. knowledge factors
2. practical factors
3. military standards/requirements
4. professional qualifications

Learning Objective: Identify types of training manuals and how they are numbered.

1-23. What kind of training manual is Aviation Support Equipment Technician M 3 & 2, NAVEDTRA 10315-B?
1. Basic
2. Rating
3. General
4. Subject matter

1-24. The word basic, as used in Rate Training Manual titles, has which of the following meanings relative to the material in the basic manual?
1. The material is common to several Navy ratings
2. The material should be studied by all Navy personnel
3. The material is simple and fundamental enough to be understood by beginners
4. The material is basic or fundamental to the rating from which the manual's title is derived

1-25. NAVEDTRA 10061 (Series) may help you in planning your study program for advancement because it lists the
1. recommended and required rate training manuals
2. applicable correspondence courses and training manuals
3. minimum requirements for advancement
4. recommended correspondence courses

1-26. The fundamental purpose of a Rate Training Manual is to
1. aid personnel to advance
2. offer advanced study to graduates of Navy schools
3. teach specific equipments to personnel in specific ratings
4. cover the professional and military aspects of specific rates

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Learning Objective: Indicate recommended ways to study a training manual.

1-27. What is the first step to take in starting your study of a Rate Training Manual?
1. Read the chapter headings
2. Outline the entire manual
3. Familiarize yourself with the entire manual
4. Prepare a list of questions to be answered as study progresses

1-28. The reasons why suggestions 4 and 7 are included in the list of study suggestions given in your textbook is that in following them you
1. write an outline of the manual which will be a valuable reference for future study
2. are able to peg each subject to an individual qualification as given in the "Quals" Manual
3. are able to separate the military qualifications from the professional qualifications in the textbook
4. familiarize yourself with the aims and contents of the manual and relate the subject areas to your past experiences thereby creating an excellent learning situation

1-29. You ask a shipmate to tell you what the textbook he is studying says about a given subject and he answers "I know what it says but I can't put it into words." What can you infer from his statement?
1. The textbook is poorly written
2. He has not really learned the information presented
3. The textbook information cannot be stated in words other than those used in the book
4. He does not desire to let you know what he has learned

1-30. When must you successfully complete the E-4 or E-5 military/leadership examination?
1. At the same time the professional examination is administered
2. Prior to participating in the professional examination
3. After successfully completing the professional examination
4. At any time, as appropriate

Learning Objective: Recognize proper procedures for the issue and turn-in of tools, and the importance of tool inventory.

1-31. The issuing of tools to an ASM is the responsibility of
1. the shop chief
2. the division chief
3. repair shop personnel
4. toolroom personnel

1-32. Upon completion of a job, what main purpose is served by the reinventory of tools taken to the job?
1. It aids in keeping track of tools issued
2. It is a check for tools against the toolroom allowance
3. It is a check for tools left within or around the equipment
4. It provides a check of tools that are on temporary custody

1-33. When a repair job which requires the use of a special tool for several days is in progress, when should the tool be returned to the toolroom?
1. As directed by the division chief
2. Immediately after the CDI has completed his inspection
3. After QA has inspected and approved the repairs
4. When the job is completed or at the end of the day

Learning Objective: Identify various types of handtools, their operating and design characteristics, and their proper uses and care.

1-34. For which of the following operations are diagonal pliers best suited?
1. Grasping cylindrical objects
2. Cutting objects flush with the surface
3. Bending heavy gage material
4. Straightening bent cotter pins

1-35. What advantage does a 6-point socket have over a 12-point socket?
1. It has a 6-point drive
2. Each of its flats allows a 30-degree turning movement
3. It is not subject to as much wear when used on stainless steel nuts
4. It needs to be swung only half as much before it is lifted and fitted for a new grip

1-36. The size of 6-point and 12-point socket openings are graduated in increments of
1. 1/16 in.
2. 1/8 in.
3. 1/4 in.
4. 3/8 in.

Items 1-37 and 1-38 refer to the following socket wrench handles.
A. Speed handle
B. Ratchet handle
C. Sliding T-bar handle
D. Hinged handle

1-37. Which handle has a built-in reversible feature?
1. A
2. B
3. C
4. D

1-38. In order to remove a nut in a hurry utilizing A, the nut should first be loosened by using
1. B only
2. B or C only
3. D only
4. B, C, or D

1-39. Which of the socket wrench accessories illustrated in figure 2-2 of your textbook should you use to turn a 1/4-inch square drive socket with a 3/8-inch square drive handle?
1. Adapter
2. Extension bar
3. Universal joint
4. Universal socket

1-40. When a nut is turned with an adjustable wrench, which of the following procedures should NOT be used?
1. Setting the jaw to grip the nut firmly
2. Gripping the nut in the throat of the jaw
3. Drawing the handle toward the adjustable jaw
4. Using a pipe extension for more leverage

1-41. A damaged common screwdriver may be repaired by the use of a/an
1. file
2. emery wheel
3. whetstone
4. oilstone

1-42. Using a Reed and Prince or Phillips screwdriver on the wrong type of screw will damage the
1. work
2. screwhead
3. screwdriver
4. worker

1-43. For a bolt to hold tight enough and NOT break when pressure is exerted against it, it must be properly tightened by a
1. socket wrench
2. box-end wrench
3. torque wrench
4. open-end wrench

1-44. Refer to table 2-1 in your textbook. Six ounce-inches of torque equal how many gram-centimeters of torque?
1. 12
2. 24
3. 216
4. 432

1-45. Which type of torque wrench can be preset to the desired torque?
1. Deflecting beam
2. Micrometer setting
3. Rigid frame
4. Dial indicating

1-46. To determine the proper torque to apply to a fastener, to what publication should you refer?
1. The maintenance manual for the equipment
2. The torque value conversion table
3. The torque wrench calibration instruction
4. The torque wrench accuracy range table

1-47. How often should a torque wrench be tested?
1. Every 15 days
2. Every 25 days
3. Every 30 days
4. Every 60 days

1-48. What type of hammer or mallet should normally be used to straighten thin sheet metal ducting?
1. Ball peen hammer
2. Plastic mallet
3. Rawhide mallet
4. Metal hammer

1-49. If a hardened steel surface must be struck and a soft hammer is NOT available, the surface should be protected by a piece of
1. copper only
2. copper or brass only
3. brass or lead only
4. copper, brass, or lead

In items 1-50 through 1-53 concerning holding tools, select from column B the pliers associated with each statement listed in column A.

	A. Statements	B. Pliers
1-50.	Can be clamped and locked in position by pulling the lever toward the handle	1. Duckbill 2. Needle-nose
1-51.	Suited for use in confined areas where fingers cannot be used	3. Channel-lock
1-52.	Contains coarse jaw teeth for grasping cylindrical objects	4. Vise grip
1-53.	Contains a side cutter near the throat and serrations near the nose end	

1-54. What tool is designed to retrieve small objects from places that are inaccessible by hand?
1. Mechanical fingers
2. Needle-nose pliers
3. Slip-joint pliers
4. Duckbill pliers

Learning Objective: Relative to special tools and equipment utilized by the ASM, identify uses and operating characteristics/techniques.

1-55. If a four-cycle engine's speed (rpm) is obtained by holding the tip of a manual tachometer against the camshaft, the speed is read as
1. four times the pointer indication on the dial
2. twice the pointer indication on the dial
3. the pointer indication on the dial
4. half the pointer indication on the dial

1-56. When used on a gasoline engine, where is the electric tachometer connected?
1. To the primary circuit
2. To the secondary circuit
3. To the battery circuit
4. To the number one spark plug

1-57. When the compression tester is used, how many engine revolutions are necessary to check the proper functioning of the rings, valves, and gaskets?
1. One
2. Two
3. Three
4. Four

1-58. Trouble which must be corrected before satisfactory engine performance can be expected is indicated if, after connecting a cylinder leakage tester to a cylinder, you can hear air escaping through the
1. carburetor only
2. exhaust pipe or the carburetor only
3. crankcase filter pipe only
4. exhaust pipe, carburetor, or crankcase filter pipe

1-59. When a vacuum gage is used, which of the following rules must be adhered to in order to obtain an accurate reading?
1. The gage must be placed or held in a vertical position
2. The connection between the intake manifold and the gage must be loose
3. All restrictions or dirt must be removed from the intake manifold and gage openings
4. The engine must be turned over one revolution

In items 1-60 through 1-63 concerning the use of the vacuum gage to diagnose engine trouble, select the malfunction from column B that causes each gage indication listed in column A.

A. Indications		B. Malfunctions	
1-60.	Reading changes slowly between 14 and 16 inches	1.	Compression leak past the piston rings
1-61.	Reading of 15 inches when cruising at 40 mph	2.	Valve timing incorrect
1-62.	Steady reading of 10 inches	3.	Improper carburetion at idle
1-63.	Bouncing reading from normal to below normal and back	4.	Sticking valve

---

1-64. Although smoke from an oil burning engine does NOT materially affect the reading of the exhaust gas analyzer, continued use of the analyzer on oil burning engines will

1. dull its sensitivity
2. cause irreparable corrosion problems
3. short out the analyzer
4. require replacement of the analyzer

1-65. Which of the following resistance creating devices may be used as a dynamometer to absorb energy?

1. A hydraulic cylinder
2. An electric armature revolving in a magnetic field
3. A fan revolving in compressed air
4. A mechanical spring

1-66. Which of the following statements concerning the chassis dynamometer is INCORRECT?

1. Its use eliminates the interference of body noise
2. It can be used to test and adjust automatic transmissions
3. It can be used to test an engine without removing the engine from the vehicle
4. It can be used to balance the front end

1-67. Where is the ignition light hooked up for checking the timing on an engine?

1. To the number one cylinder
2. To the number two cylinder
3. To the number three cylinder
4. To the number four cylinder

Assignment 2

Tools and Lifting Services and Aviation Support Equipment

Text: Pages 43 - 81

Learning Objective (Continued): Relative to special tools and equipment utilized by the ASM, identify operating and design characteristics, operating techniques, and uses.

2-1. In addition to removing small pits or burns from the faces of valves, the valve refacer can also be used to
1. square tappets
2. square valve stems
3. grind push rods
4. grind valve seats

In items 2-2 through 2-5, select from column B the components of valve seat grinders that are associated with each statement listed in column A.

A. Statements

2-2. They are available in three grades--for cast iron, hard steel, and finishing

2-3. They are threaded on one end for attaching the stone

2-4. They provide a rigid axis for the grinding stone sleeves

2-5. They incorporate a positive vibrating action to minimize stone loading, speedup grinding, and reduce stone wear

B. Components

1. Drivers
2. Valve guide pilots
3. Valve seat grinding stone sleeves
4. Valve seat grinding stones

2-6. The final process of fitting a newly ground valve and seat consists of rubbing the valve seating face against the valve seat. This is accomplished by using a
1. valve guide
2. valve lapper
3. valve refacer
4. self-centering valve guide pilot

2-7. If a valve spring is used that does NOT meet the tension requirements listed in the engine manufacturer's manual, which of the following would NOT result?
1. Undue wear on the valve operating mechanism
2. The valve may not seat properly
3. The valve may burn
4. An elongated valve

2-8. What tool is used when the valve spring retaining locks are removed from the valve stem?
1. Valve spring tester
2. Self-centering valve guide pilot
3. Valve spring compressor
4. Valve retaining punch

2-9. When the spark plug cleaner is used, sand is air blasted against the electrode end of a spark plug to
1. eliminate high-pressure plug firing failure
2. remove the cleaning solvent
3. eliminate too small a gap between electrodes
4. remove carbon deposits

2-10. Which of the following statements concerning air compressors is correct?
1. A gasoline driven compressor is usually placed inside the shop
2. A governor controls the unloader valve of a gasoline driven compressor
3. A pressure of 80 psi is normally the maximum pressure setting of the automatic control
4. A hand throttle controls the automatic underloader valve on the compressor

2-11. Which of the following statements concerning permanently installed lubrication equipment is INCORRECT?

1. High-pressure lines carry the lubricants from the containers to the guns
2. Switching a slot pin in the handle of the gun will determine whether high- or low-pressure will be delivered
3. Permanent installations can be used for chassis lubricants, gear lubricants, automatic transmission fluids, and air
4. Air-operated pumps are located on the lubricant containers

2-12. Refer to figure 2-45 in your textbook. This installation is NOT equipped to handle which of the following kinds of lubricants?

1. Gear lubricants
2. Chassis lubricants
3. Automatic transmission lubricants
4. Powdered graphite

In items 2-13 through 2-16 refer to figures 2-49 through 2-51 and 2-53 in your textbook. Select the components listed in column B that make up each puller listed in column A.

A. Pullers

2-13. Universal bearing and bushing puller

2-14. Push and pull puller set

2-15. Universal wheel puller set

2-16. Slide hammer puller set

B. Components

1. A pressure screw with slide bar, a U-shaped body, a jaw holder, two large jaws, two small jaws, and two jaw pins
2. A two- and three-way yoke, three medium jaws, two small jaws, and a locking feature
3. A body and drive assembly, three long jaws, a special grooved hub set, and tapered right- and left-hand threaded stud nuts
4. A 13 1/2-inch steel slotted bar to receive pairs of legs, of various lengths, a 1-inch threaded pressure screw 13 inches long, and numerous attachments and adapters

2-17. Refer to figure 2-56. When the universal push and puller set is used to remove a camshaft gear from an engine without removing the camshaft, the tightening force is applied to the

1. case
2. engine
3. camshaft
4. camshaft gear

2-18. Refer to figure 2-57. When the universal push and puller set is used to remove a bevel pinion shaft from a transmission, the tightening force is applied to the

1. bevel gear
2. pinion shaft
3. transmission case
4. cam gear

2-19. Refer to figures 2-52 and 2-60 in your textbook. What component of the cylinder sleeve puller is adjustable to the position of the cylinder head studs and is used to center the tool in the cylinder?

1. Adaptor plate
2. Forcing screw
3. Three-way head
4. Extension and swivel assembly

Learning Objective: Recognize the different types of lifting devices and their characteristics and uses.

In items 2-20 through 2-22, select from column B the type of jack that is best suited for each situation listed in column A.

A. Situations

2-20. The required capacity is small

2-21. The required capacity is great and the extended heights vary

2-22. Parts are to be pulled together or pushed apart

B. Jacks

1. Rack bar or screw
2. Outrigger
3. Vertical hydraulic

2-23. Which of the following types of jacks can be used to perform the greatest number of different types of operations?

1. Vertical hydraulic
2. Push-pull hydraulic
3. Vertical screw
4. Outrigger screw

2-24. Of the hoists listed, what is the correct descending order of efficiency?
1. Screw gear hoist, spur gear hoist, and differential hoist
2. Spur gear hoist, screw gear hoist, and differential hoist
3. Spur gear hoist, differential hoist, and screw gear hoist
4. Differential hoist, screw gear hoist, and spur gear hoist

2-25. As a safety measure, which part of a hoist is intentionally built the weakest and requires close observation for signs of overloading?
1. The chain
2. The shell of the upper block
3. The lower hook
4. The upper hook

Learning Objective: Indicate safety precautions to be followed in performing tasks with tools, and results if these precautions are NOT followed.

2-26. Should gasoline or other flammable liquid be spilled on the shop floor, which of the following procedures is NOT recommended?
1. Turn on the exhaust fan or open all doors and windows to dispel vapors
2. Wipe up the liquid and dispose of the rags in a covered container
3. Cover the spot with sweeping compound before sweeping it up
4. Flush with water

2-27. Compressed air, when used for power tools, is classified as a possible hazard because
1. the compressed air may be contaminated
2. at close range compressed air can bruise or otherwize injure the body
3. compressed air can expand tolerances within the tool and make it a hazard
4. it may be used inside buildings

2-28. Smoking should be permitted in a shop only if
1. the weather does not permit smoking outside
2. smoking areas are marked off
3. the windows and doors are open
4. there are no flammable materials in the shop

Learning Objective: Identify types, uses, capabilities, and characteristics of aviation handling equipment.

2-29. Which of the following types of handling equipment used in the support of naval aviation is NOT the responsibility of the ASM?
1. NS-60 cranes
2. Tow bars and tow tractors
3. Chocks and tiedowns
4. B & H cranes

In items 2-30 through 2-33, select from column B the tow tractor that has each characteristic listed in column A.

A. Characteristics

2-30. It has a drawbar pull of 8,500 pounds

2-31. It has a gross weight of 25,800 pounds

2-32. It has a pushbutton-controlled automatic transmission

2-33. It has a rear-mounted gas turbine compressor

B. Tow Tractors

1. TA-18
2. MD-3A
3. TA-75
4. MC-2

2-34. Which of the following tow tractors exerts the greatest drawbar pull?
1. MD-3
2. MD-3A
3. TA-18
4. TA-75A

2-35. Where can you find information concerning the correct tow bar to be used with a particular aircraft?
1. The Aircraft Flight Manual for that type of aircraft
2. The handbook for the type of aircraft tow vehicle to be used
3. The manufacturer's instructions for that type of aircraft
4. The aircraft's "Yellow Sheet"

2-36. The universal chock used aboard aircraft carriers is adjustable to fit any landing gear wheel up to a maximum of how many inches in diamter?
1. 45 in.
2. 47 in.
3. 50 in.
4. 55 in.

2-37. What is the most common type of tiedown used aboard aircraft carriers?
1. Hurricane tiedown
2. TD-1A
3. TD-4
4. Wire rope

In items 2-38 through 2-43, select from column B the mobile crash crane that has each characteristic listed in column A.

	A. Characteristics	B. Crash Cranes
2-38.	Designed for lifting, maneuvering, and removing crashed aircraft from air station runways and surrounding areas	1. NS-50 2. MB-1A
2-39.	Designed to lift and carry crashed aircraft on the flight deck of aircraft carriers	
2-40.	Operated by ac power and moved by dc power	
2-41.	Operated by ac power and moved by a prime mover powered by a diesel engine	
2-42.	Equipped with electrically-controlled multiple disc brakes	
2-43.	Equipped with pneumatically air-controlled disc brakes	

Learning Objective: Recognize capabilities and operating characteristics of ground support equipment, including applicable maintenance procedures and safety precautions.

2-44. Which of the following electrical power units is/are self-propelled?
1. NC-2A only
2. NC-10 and NC-12 only
3. NC-2A and NC-12 only
4. NC-2A, NC-10, and NC-12

2-45. Which electrical power unit is designed for starting aircraft aboard a carrier in case the deckedge power is disrupted?
1. NC-2A
2. NC-5
3. NC-10
4. NC-12

2-46. The NC-2A is powered by a/an
1. gasoline engine
2. electric motor
3. diesel engine
4. hydraulic pump

2-47. The front axle, 28 vdc motor is capable of driving the NC-2A up to a maximum speed of
1. 5 mph
2. 10 mph
3. 14 mph
4. 24 mph

2-48. How many cylinders does the NC-8A diesel engine have?
1. Six
2. Two
3. Three
4. Four

2-49. What does the NC-10B furnish to an aircraft for power?
1. 90 kva, 120/208 vac, 3 phase, 400 Hz
2. 60 kva, 120/208 vac, 3 phase, 400 Hz
3. 30 kva, 110/200 vdc, 3 phase, 200 Hz
4. 30 kva, 110/200 vac, 2 phase, 400 Hz

2-50. Motor generator assemblies supply ac and dc power for aircraft servicing and component testing. This power must possess what characteristics?
1. High voltage and high current
2. High voltage and low current
3. Low voltage and high current
4. Low voltage and low current

2-51. The various types of forklift trucks which the ASM may be required to maintain will be powered by
1. gasoline engines only
2. diesel engines only
3. electrical engines
4. either gasoline or diesel engines

2-52. What restrictions, if any, are there with reference to personnel operating forklifts?

1. The operator must have 20/20 vision (corrected)
2. The operator must be a rated man
3. The operator must be licensed
4. None; anyone may operate a forklift

2-53. The two-cylinder, air-cooled engine of the NPH-3 portable preheater drives the

1. vehicle
2. generator only
3. ventilating air blower only
4. generator and air blower

2-54. Air-conditioning units are identified by which letter designation?

1. NC
2. AC
3. NR
4. NB

2-55. An NR-5C air conditioner is used to cool an aircraft's

1. engines
2. exhaust gases
3. cabin
4. generator(s)

2-56. The NR-5C is powered by a/an

1. diesel engine
2. electric motor
3. gasoline engine
4. set of batteries

2-57. Gas turbine power units are driven by

1. diesel engines
2. gas engines
3. electric motors
4. gas turbine engines

2-58. What do the gas turbine units used in ground support equipment supply?

1. Air for aircraft starters
2. Refrigeration for aircraft cabins
3. Power drive for tow tractors
4. Refrigeration for pilot comfort

2-59. What are the two pressures of compressed air supplied by the NCPP-105?

1. 5:2 and 3:0
2. 5:1 and 3.6:1
3. 5:1 and 3.6:3
4. 5:1 and 5.6:3

2-60. How are the lifting and handling functions of the 47A weapons loader powered?

1. Electrically only
2. Mechanically only
3. Hydraulically
4. Electrically and mechanically

2-61. Should mechanical or hydraulic failure of the 47A weapons loader occur, the load will

1. slowly lower to the "at-rest" position
2. rise to the highest position
3. automatically set the parking brake
4. remain stationary

2-62. Which of the following statements about the P-36 airfield maintenance truck is INCORRECT?

1. It has a coil and distributor type of ignition system
2. Its air-cooled, 34-horsepower engine has four cylinders
3. Both its transmission and steering are manually operated
4. It has pneumatically-operated shoes located in the front wheel brake drums

2-63. The P-36 airfield maintenance truck is better suited for use on paved surfaces than on nonpaved surfaces because of its

1. air-cooled engine
2. open operator's compartment
3. five-inch clearance
4. 34-horsepower engine

2-64. What is the purpose of oil being sprayed on the underside of the pistons in the engine?

1. To increase oil flow
2. To assist in piston cooling
3. To increase piston heating
4. To increase engine speed

2-65. What will NOT decrease the warmup time and maintain the proper operating temperature of the engine?

1. The regulator valve in the water jacket
2. The thermostatically controlled radiator shutters
3. The NPH-3 portable preheater
4. The heat riser

2-66. The MB-5 has a semiautomatic transmission that provides (a) how many speeds forward and (b) how many speeds in reverse?

1. (a) 4 (b) 2
2. (a) 3 (b) 1
3. (a) 4 (b) 1
4. (a) 4 (b) 4

2-67. When the transmission is in low gear, at what speed should the engine be running before shifting to the next higher gear?

1. 2,200 rpm
2. 2,300 rpm
3. 2,400 rpm
4. 2,500 rpm

2-68. How many ways can the auxiliary generator be started?
1. One
2. Two
3. Three
4. Four

2-69. What is the "using" division onboard carriers?
1. V-1 division
2. V-2 division
3. GSE division
4. V-4 division

2-70. The hydraulic test stand is connected to the aircraft's hydraulic systems by
1. quick disconnects
2. b-4 nuts
3. bayonet fittings
4. plug ins

2-71. What type of pump does the AHT-63 hydraulic unit have?
1. Rotary piston
2. Axial piston
3. Gear rotary
4. Axial gear

2-72. The AHT-63 test stand is capable of circulating 13 gallons of hydraulic fluid per minute through the system at a pressure of
1, 1,000 psi
2. 3,000 psi
3. 3,500 psi
4. 5,000 psi

2-73. The gasoline engine that powers the steam cleaner transfers its power to the pumps, magneto, and fan via a
1. V-belt
2. direct coupling
3. geared coupling
4. fluid drive assembly

2-74. What fuel is used in steam cleaners to heat the cleaning compound?
1. Kerosene
2. Diesel fuel
3. Aircraft gasoline
4. Automotive gasoline

2-75. The portable dry honing machine is primarily used with
1. ground support equipment
2. aircraft and aircraft components
3. hoisting slings
4. ordnance support equipment

Assignment 3

Aviation Support Equipment, Physics

Text: Pages 82 - 106

Learning Objective (Continued): Recognize capabilities and operating characteristics of ground support equipment, including applicable maintenance procedures and safety precautions.

3-1. What type of abrasive should be used in the dry honer on metal that will corrosively react with aluminum?
1. Soft grit
2. Glass beads
3. Aluminum oxide
4. Sand

3-2. The dry honing machine operates satisfactorily on air pressures and flow ranging from
1. 80 to 90 psi and 70 to 80 cubic feet per minute
2. 80 to 100 psi and 80 to 90 cubic feet per minute
3. 90 to 100 psi and 60 to 70 cubic feet per minute
4. 100 to 110 psi and 90 to 100 cubic feet per minute

3-3. What must be done when working with the dry honer to prevent the loss of abrasivies?
1. The blast control valve must be released before the gun is raised from the surface
2. The blast control valve must be released before the gun is pressed to the surface
3. The blast control valve must be released at all times
4. The blast control valve must be closed at all times

3-4. Inasmuch as the P5R air compressor can be used to charge both low-and high-pressure aircraft pneumatic systems, what is the charging range of the air compressor?
1. 0 to 1,000 psi
2. 0 to 2,500 psi
3. 0 to 3,000 psi
4. 0 to 5,000 psi

3-5. The P5R air compressor's engine speed is controlled by what type of governor?
1. Vacuum
2. Mechanical
3. Centrifugal flyball
4. Hydraulic

3-6. The unpowered truck dollies are commonly referred to as
1. tractor dollies
2. crash dollies
3. vehicle dollies
4. aircraft dollies

3-7. Relative to the maintenance of unpowered trailers, dollies, and carts, ASMs are responsible for which of the following tasks?
1. Repair
2. Lubrication
3. Component replacement
4. Painting

3-8. Movement and spotting of an aircraft where very little maneuvering room is available can best be accomplished by the use of the
1. MD-1A
2. MD-3
3. SD-1D
4. TD-1A

3-9. What must you do to the handle at the end of the control arm of the SD-1D aircraft spotting dolly to control the forward and backward movements of the dolly?
1. Push it to the right or to the left
2. Push it forward or pull it backward
3. Depress or raise it
4. Twist it

3-10. What is the maximum lifting weight of the SD-1D spotting dolly?
1. 16,000 lb
2. 26,000 lb
3. 36,000 lb
4. 46,000 lb

3-11. What equipment should be used when an entire aircraft is to be jacked?
1. Tripod jacks
2. Single-base jacks
3. Tripod jacks in conjunction with a sling hoist
4. Single-base jacks in conjunction with a sling hoist

3-12. You discover heavy gasoline leakage from a vehicle. In addition to reporting the condition you should
1. place a warning lantern near the vehicle
2. start the engine and move the vehicle to another spot
3. warn others of the danger of vapors
4. close the windows of the vehicle immediately

Learning Objective: Recognize the ASM's need for understanding the basic laws of physics, and identify the basic concepts of measurement.

3-13. The three broad categories of measurement are
1. magnitude, volume, and time
2. height, length, and width
3. direction, location, and time
4. direction, magnitude, and time

3-14. Which measurement is based on a combination of magnitudes?
1. Size
2. Temperature
3. Pressure
4. Frequency

3-15. Which measurement is based on a combination of measurement categories?
1. Speed
2. Voltage
3. Distance
4. Pressure

Learning Objective: Identify basic terms and principles relating to matter, and solve problems concerned with gases.

3-16. What is the smallest unit into which a drop of water can be divided and still retain the characteristics of water?
1. Atom
2. Proton
3. Molecule
4. Electron

3-17. Oxygen will retain its characteristics after it has been subdivided into
1. atoms
2. protons
3. neutrons
4. electrons

3-18. The weight of an atom is contained almost entirely in the atom's
1. nucleus
2. protons
3. neutrons
4. electrons

3-19. When is the atom considered electrically neutral?
1. When there are two electrons for one proton in the entire atom
2. When there is one electron for each proton in the entire atom
3. When there is one electron for every two protons in the entire atom
4. When there are four electrons for each two protons in the entire atom

3-20. What prevents electrons from being drawn toward the nucleus?
1. Atomic weight
2. Centrifugal force
3. Centripetal force
4. Electrical repulsion

3-21. What does the chemical combination of two or more elements form?
1. An isotope
2. A mixture
3. A compound
4. A new element

3-22. What is the atomic number of an element?
1. The weight of its nucleus
2. The number of its orbiting electrons
3. The sum of its protons and electrons
4. The number of protons in its nucleus

3-23. Ordinary drinking water if formed from what two gases?
1. Hydrogen and carbon fluids
2. Hydrogen and carbon dioxide
3. Hydrogen and oxygen
4. Oxygen and carbon dioxide

3-24. The three natural states in which matter may exist are
1. fluid, porous, and vapor
2. solid, liquid, and gas
3. electron, proton, and neutron
4. physical, chemical, and nuclear

3-25. What characteristic of molecules determines the state of the matter they form?
1. Their weight
2. Their magnitude
3. The extent of their motion
4. The amount of heat they contain

In items 3-26 through 3-28, select from column B the physical description that applies to each state of matter listed in column A.

A. States of Matter	B. Physical Descriptions
3-26. Solid	1. Has a definite volume but no definite shape
3-27. Liquid	
3-28. Gas	2. Has neither a definite volume nor a definite shape
	3. Has a definite volume and a definite shape
	4. Has an indefinite volume and definite shape

3-29. Oil from a crankcase clings to a metal dipstick because of the oil's
1. ductility
2. cohesion
3. adhesion
4. elasticity

3-30. Steel can NOT be pulled apart easily because
1. its molecules exert a slight cohesive force between themselves
2. cohesion and adhesion between its crystals serve to bond them together
3. its molecules exert a great molecular force that resists separation
4. a tremendous adhesive force between its molecules causes them to cling together

3-31. Which of the following statements concerning liquids is INCORRECT?
1. The utilization of hydraulic machinery permits liquids to be used to alter input forces and to gain advantage in distance and pressure
2. Energy is transmitted through liquids practically instantaneously and equally in all directions with little or no loss in power
3. Being completely flexible, liquids can easily transmit energy around bends, thereby making remote locations of servos possible
4. Liquids provide an excellent mechanical advantage because of their fluidity and their compressible nature

3-32. What is the advantage of the hydraulic servomechanism system over the electrical servomechanism system?
1. The electrical servo requires less build up time
2. The hydraulic servo requires two workers to build up
3. The two systems will require the same build up time
4. The hydraulic servo will build up faster than the electrical servo

3-33. Since there are 25.4 millimeters in each inch, standard pressure is represented by how many inches of mercury?
1. 25.40 in.
2. 27.52 in.
3. 29.92 in.
4. 30.02 in.

3-34. A gage reading of the pressure in an automobile tire represents the
1. local atmospheric pressure plus the absolute pressure
2. absolute pressure minus the local atmospheric pressure
3. local atmospheric pressure minus the atmospheric pressure
4. aboslute pressure

3-35. An absolute pressure of 37.6 psi at sea level may be obtained by
1. adding 76 psi to a gage pressure of -38.4 psi
2. changing gage pressure to atmospheric pressure
3. subtracting 17.7 psi from a gage pressure of 52.3 psi
4. adding 14.7 psi to a gage pressure of 22.9 psi

3-36. According to the kinetic theory, which of the following statements concerning absolute zero is correct?

1. It is the temperature at which no heat remains in a gas, but not the lowest temperature obtainable
2. It has been attained only once at which time the absolute zero point of -273.16° C was determined
3. It is the temperature at which it is belived that all molecular activity in a substance ceases
4. It is the temperature to which liquids, solids, and gases can be reduced and at which most molecular activity ceases

3-37. Use Boyle's law to solve the following problem. A gas is confined in 30 cubic feet of space at an absolute pressure of 50 psi. If the volume of the space is changed so that the pressure is increased to an absolute value of 100 psi, what is the new volume in cubic feet?

1. 13.4 ft^3
2. 15 ft^3
3. 19.4 ft^3
4. 60 ft^3

● In solving problems involving absolute temperature it becomes necessary to convert Celsius (centigrade) to absolute by adding 273 degrees to the Celsius reading. Thus, 15° C equals 288° absolute.

3-38. Use Charles' law to solve the following problem. If the volume of a gas is 400 cubic feet at a temperature of 10° C, what will be its volume in cubic feet if the temperature is raised to 60° C?

1. 470.67 ft^3
2. 476.70 ft^3
3. 2,300 ft^3
4. 4,200 ft^3

3-39. If it is observed that the pressure of gas in a sealed container has increased, it can be assumed that

1. heat has been absorbed by the gas
2. heat has been removed from the gas
3. the kinetic energy of the gas has decreased
4. molecules of the gas have gained energy from each other while colliding

3-40. The general gas equation used in the study of gases is a combination of the gas laws of

1. Charles and Boyle only
2. Charles and Kelvin only
3. Boyle and Fahrenheit
4. Boyle, Charles, and Kelvin

3-41. If a tank containing 700 cubic inches of air at a gage pressure of 30 psi and temperature of 10° C is heated to 35° C, the gage pressure in psi will be

1. 30.3 psi
2. 32.7 psi
3. 33.9 psi
4. 39.3 psi

Learning Objective: Identify terms involving mechanics, recognize terms and principles concerning force, mass, and motion, and solve problems dealing with these principles.

3-42. What is the approximate location of the center of gravity of the earth?

1. Along the Equator
2. Near the center of the earth
3. At the point where the 0° meridian intersects the Equator
4. At the junction of the Equator and the International Date Line

3-43. Refer to figure 4-4 in your textbook. Which of the following statements most accurately describes the two aspects of circular motion?

1. Rotation and revolution both describe the motion of a body around a fixed point, however rotation is involved with smaller bodies
2. Rotation and revolution both describe the motion of a body around an axis, however revolution is involved with larger bodies
3. Revolution describes the motion of a body around its axis, while rotation describes the motion of a body around an exterior point
4. Rotation describes the motion of a body around its axis, while revolution describes the motion of a body around an exterior point

3-44. In the study of masses in motion, the term acceleration describes a

1. body that is moving
2. body at rest or moving
3. condition commonly called velocity
4. change in a body's speed or direction of travel

3-45. If an identical pushing force is applied to a one-cubic foot block of lead and also to a one-cubic-foot block of wood both resting on a smooth, horizontal surface, their reactions will be such that

1. the two blocks will move the same distance
2. because of its greater mass the lead block will move farther than the wood block
3. because of its lesser mass the wood block will move farther than the lead block
4. the two blocks will move the same distance, but the lead block will move move more slowly

● In mathematics, any quantity multiplied by zero is zero; that is $3 \times 0 = 0$.

3-46. The acceleration of a body is determined by the ratio of applied force to its mass. In the formula $F = ma$, if a is zero, as in the case of a vehicle traviling at a constant speed in a given direction, force is

1. zero
2. changing
3. infinite
4. impossible to determine unless the speed is known

3-47. Newton's second law of motion is expressed by the formula $a = \frac{F}{m}$, which can be converted to $F = ma$, and indicates that

1. force is inversely proportional to the product of the mass of a body and its acceleration
2. the mass of a body is determined by the sum of its acceleration and the external force acting on it
3. acceleration is inversely proportional to the force acting on a body and directly proportional to its mass
4. acceleration is directly proportional to the force acting on a body and inversely proportional to its mass

3-48. If an automobile weighs 2,000 pounds attains a speed of 60 miles per hours, its momentum is

1. 100,000 ft-lb/hr
2. 110,000 ft-lb/hr
3. 120,000 ft-lb/hr
4. 150,000 ft-lb/hr

3-49. A pump lifts 1,000 gallons of a liquid which weighs 8 pounds per gallon through a vertical distance of 125 feet. In foot-pounds, what is the amount of work done?

1. 1,000 ft-lb.
2. 1,250 ft-lb.
3. 1,000,000 ft-lb.
4. 1,250,000 ft-lb.

3-50. An elevator lifts an aircraft weighing 30 tons a distance of 25 feet in 6 seconds. What is the approximate horsepower developed?

1. 330 hp
2. 450 hp
3. 550 hp
4. 740 hp

● In answering items 3-51 through 3-53, assume that the water system of a naval installation requires the expenditure of 2,000,000,000 foot-pounds of energy during a 24-hour period.

3-51. What is the average horsepower produced by the pumps?

1. 42.09 hp
2. 84.18 hp
3. 210.45 hp
4. 420.90 hp

3-52. Assuming 100 percent efficiency, how many watts of electrical power are used to produce the mechanical power expended by the pumps?

1. 15,699.93 W
2. 31,399.14 W
3. 94,197.42 W
4. 165,599.70 W

3-53. If the pumps are only 50 percent efficient, how many watts of electrical energy are required?

1. 31,399.14 W
2. 62,798.28 W
3. 188,394.84 W
4. 331,199.40 W

3-54. Ten horsepower are required to operate a generator which has an output of 1,000 watts. What is its efficiency?

1. 13.4 percent
2. 15.3 percent
3. 25.7 percent
4. 30.1 percent

3-55. Which of the following is NOT an illustration of friction?
1. The action of skates against ice
2. The use of brakes by a landing aircraft
3. The contact of an airborne aircraft with the air
4. A rotating wheel

3-56. Refer to figure 4-5 in your textbook. A plank is used as a lever to raise a 100-pound weight. Assume that D_1 is 10 feet and D_2 is 2 feet. How much force, in pounds, is needed?
1. 20 lb
2. 40 lb
3. 90 lb
4. 100 lb

3-57. Refer to figure 4-6. When the knot slipped, the path the ball traveled in reaching the 10-foot radius was
1. curved, and is not shown in the figure
2. curved, and is represented by the line labeled LINEAR PATH
3. straight, and is the unlabeled 10-foot radius
4. straight, and is labeled LINEAR PATH

Learning Objective: Identify principles of wave motion and solve associated problems.

3-58. The reason water waves are termed transverse waves is because the particles of water move in what manner?
1. In the same direction the wave is traveling
2. In the direction opposite to that in which the wave is traveling
3. At a right angle to the direction the wave is traveling
4. At a horizontal right angle to the direction the wave is traveling

3-59. Why are sound waves longitudinal and water waves transverse?
1. Sound wave particles vibrate from side to side, while water particles move up and down
2. Sound wave particles vibrate from side to side, while water particles move in the direction of wave travel
3. Sound causes particle vibration 90 degrees to the direction of wave travel, while water particles move up and down
4. Sound causes particle vibration in the direction of wave travel, while water particles move up and down

3-60. Refer to figure 4-7 in your textbook. How many complete cycles of sound are shown emitting from the tuning fork?
1. Six
2. Five
3. Three
4. Four

3-61. What is the period of one cycle of sound whose frequency is 20 hertz?
1. 5.0 sec
2. 0.5 sec
3. 0.05 sec
4. 0.005 sec

3-62. The wavelength of a wave can be determined by measuring the
1. distance across the positive peak along the zero line
2. vertical distance from the positive peak to the zero line
3. vertical distance from the positive peak to the negative peak
4. horizontal distance between maximum points on successive waves

3-63. Refer to figure 4-8 in your textbook. If a ray of light strikes a flat mirror, the angle of incidence is the angle between the incident ray and
1. a perpendicular to the surface at the point of impact
2. the surface of the mirror
3. the reflected ray
4. a perpendicular to the incident ray

3-64. Sunlight glancing from the ripples on a lake is an example of
1. regular reflection
2. specular reflection
3. diffused reflection
4. incident reflection

3-65. Refer to figure 4-11 in your textbook. If a ray passes from a more dense to a less dense medium, as shown at the lower edge of the rectangle, how is it deflected?
1. In a direction determined by the wavelength and frequency of the ray
2. Away from the normal and the angle of refraction is less than the angle of incidence (r_1 less than i_1)
3. Away from the normal and the angle of refraction is greater than the angle of incidence (i_1 less than r_1)
4. Toward the normal and the angles of incidence and refraction are determined by the relative densities of the media

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Learning Objective: Recognize terms and basic principles concerning sound.

3-66. The audible range is arbitrarily said to be from 15 hertz (Hz) to 20,000 Hz. Those sounds occurring at 15 Hz and 20,000 Hz are said to be
1. subsonic and ultrasonic, respectively
2. ultrasonic and subsonic, respectively
3. the lower and upper extremes of the audible range, respectively
4. the upper and lower extremes of ultrasonic and subsonic, respectively

3-67. Of the several factors affecting sound velocity in any medium, those having the greatest effect are
1. density and pressure
2. density and elasticity
3. pressure and elasticity
4. temperature and density

3-68. Sound travels faster through water than through air because of water's greater
1. wetness
2. fluidity
3. elasticity
4. compactness

3-69. What is the velocity of sound in air at a temperature of 32° C?
1. 1,087 ft/s
2. 1,127 ft/s
3. 1,133 ft/s
4. 1,151 ft/s

3-70. The pitch of a sound can be described as being
1. high if it contains many overtones, low if it contains few overtones
2. low if the wave is transverse, high if the wave is longitudinal
3. low if the frequency is low, and high if the frequency is high
4. high if the wavelength is long, low if the wavelength is short

3-71. The intensities of sounds having different frequencies can be compared by measuring pressure variations because
1. great pressure variations reduce sound at all frequencies to a measurable level
2. pressure variations occur at all points in the transmitting medium and tend to cancel each other's effect
3. a sound's intensity is proportional to the square of the pressure variations, and frequency need not be considered
4. the intensity of a sound is proportional to the square of the pressure variations after frequency differences have been correlated

3-72. Note C from a piano sounds different from the C of equal intensity from a violin because
1. of a difference in the number, frequency, and intensity of the harmonics in the notes
2. the fundamental tone from each instrument originates at a different frequency
3. of a difference in pitch
4. the fundamental tone from each instrument is altered in frequency by an amount proportional to the number of harmonics present

3-73. An auditorium that has good acoustics is designed to supress which of the following?
1. Echoes only
2. Echoes and reverberations
3. Reverberation only
4. Absorbtion and refraction

3-74. On a television receiver a ghost is produced by the transmitted signal being reflected from a distant object and arriving at the antenna at a later time than the direct signal. In sound this condition is called
1. an echo
2. reverberation
3. focus concentration
4. high level intensity

3-75. A disturbing echo from a loudspeaker in an auditorium can NOT be minimized by
1. locating the reflecting area and covering it with an absorbing material
2. altering the shape of the reflecting area
3. moving the loudspeaker
4. changing the volume

Assignment 4

Physics, Publications, MIARS, and Drawings

Text: Pages 108 - 128

Learning Objective: Recognize terms and basic principles concerning heat and associated problems.

4-1. The theory of radiation of energy treats radio, light, and heat waves as parts of the same general form of energy differing primarily in their
1. phase
2. polarity
3. frequency
4. magnitude

4-2. Which of the following substances is the poorest conductor of heat?
1. Wood
2. Cast iron
3. Copper
4. Aluminum

In items 4-3 through 4-5, select from column B the term which is most closely related to each definition listed in column A.

A. Definitions	B. Terms
4-3. Motion of the cooling medium that occurs without mechanical motion being applied	1. Conduction
	2. Convection
4-4. Heat transference by molecular collision	3. Radiation
4-5. Heat transference closely resembling radio wave propagation	4. Absorption

4-6. Gases are poorer conductors of heat than most solids because
1. gas molecules expend their energy in striking each other
2. the molecules in gases travel slower than those in solids
3. gas molecules do not absorb as much heat as those in solids
4. the molecules in gases are more loosely packed than those in solids

4-7. What does the transfer of heat by convection involve?
1. Electromagnetic wave motion of molecules
2. Smooth, light-colored surfaces absorbing heat
3. Heating a substance, such as air or water, that moves when heated
4. Adjacent molecules transferring heat by collision

4-8. An object that is cooled by utilizing fins employs what heat transfer processes?
1. Absorption and convection
2. Absorption and conduction
3. Conduction and radiation
4. Conduction and convection

4-9. What term identifies the transference of heat energy in the form of electromagnetic waves?
1. Radiation
2. Absorption
3. Conduction
4. Convection

4-10. Consideration of the heat transfer principle of radiation reveals that radiant heat does NOT act in which of the following ways?
1. It moves with the speed of light
2. It travels in a straight line
3. It can pass through a medium without heating it
4. It passes through any screen between it and another object

4-11. What color surface is most effective in radiating heat?
1. Dull black
2. Polished black
3. Dull silver
4. Polished silver

4-12. How many British thermal units (Btus) are required to raise the temperature of 2 pounds of water from its freezing point of 32° F to its boiling point of 212° F?
1. 180 Btu
2. 212 Btu
3. 244 Btu
4. 360 Btu

4-13. An action producing 1,764 calories of heat energy requires how many foot-pounds of mechanical energy?
1. 3,112 ft-lb
2. 3,890 ft-lb
3. 4,668 ft-lb
4. 5,446 ft-lb

● Water has a specific heat of 1 and all other substances have specific heats which relate to that of water. When two bodies of different temperatures are mixed, heat will be transferred from the warmer body to the cooler one until both reach the same temperature. The heat gained by the cooler body will equal the heat lost by the warmer body if there is no loss of heat to the environment. The formula to be used is: Heat gained = heat lost, or mass x change in temperature x specific heat of one body = mass x change in temperature x specific heat of the other body.

4-14. A piece of lead having a mass of 500 grams and heated to 292° C is dropped into 400 grams of water having a temperature of 15° C. If the temperatures become equal at 26° C, what is the specific heat of the lead?
1. 0.033
2. 0.066
3. 0.099
4. 1.333

4-15. Water is NOT suitable for use in most modern thermometers because
1. it does not expand and contract
2. it expands and contracts
3. its freezing point is too high
4. its reaction to pressure change is negative

4-16. The zero point on a Celsius thermometer coincides with the temperature of
1. frost
2. dry snow
3. solid ice
4. melting ice

4-17. The boiling point on a Celsius thermometer indicates the temperature of
1. water just as it begins to boil
2. water immediately after it boils
3. steam under a pressure of 76 cm of mercury
4. steam under a pressure of 100 cm of mercury

4-18. Normal body temperature of 98.6° F converted to Celsius is
1. 37.0° C
2. 40.0° C
3. 58.6° C
4. 66.6° C

4-19. On a day when the temperature increases from 20° F to 45° F, how many degress of increase will a Celsius thermometer indicate?
1. 13.88° C
2. 25.00° C
3. 27.76° C
4. 29.00° C

4-20. If a thermometer registers 30° C, what is the Fahrenheit equivalent?
1. 54° F
2. 62° C
3. 75° F
4. 86° F

4-21. Using the "40 rule," the Fahrenheit temperature that corresponds to a Celsius temperature of 160° is
1. 32° F
2. 80° F
3. 160° F
4. 320° F

4-22. If a thermometer indicates a temperature of -22° F, what is the corresponding Celsius temperature?
1. -30° C
2. -10° C
3. 10° C
4. 18° C

4-23. The resistance element used in the construction of resistance thermometers is normally fabricated of
1. copper
2. silver
3. mercury
4. platinum

4-24. The component of a temperature measuring device which produces an electric current is the
1. calorimeter
2. galvanometer
3. thermocouple
4. resistor

4-25. Copper can NOT be employed in conjunction with the stem or base of a vacuum tube because copper
1. and glass have the same rate of expansion
2. and glass do not have the same rate of expansion
3. has a positive coefficient of expansion while glass has a negative coefficient of expansion
4. has a negative coefficient of expansion and glass has a positive coefficient of expansion

4-26. A steel tape is exactly 100 feet long when its temperature is 20° C. If its temperature is increased to 38° C, what will be its length?
1. 100.018 ft
2. 100.180 ft
3. 101.008 ft
4. 101.018 ft

4-27. The temperature measuring device which utilizes the differences in the coefficients of expansion of dissimilar metals is the
1. thermostat
2. thermometer
3. thermograph
4. thermocouple

4-28. A hole was bored through the center of a steel plate which is 1 foot square. If the plate is heated, the hole will
1. become larger
2. become smaller
3. remain the same size
4. become larger or smaller, depending on the thickness of the plate

4-29. The number of Btus required to change a unit mass of a substance from a solid state to a liquid state with no change in temperature is known as the latent heat of
1. fusion
2. combustion
3. condensation
4. vaporization

4-30. The amount of heat required to change a liquid into a vapor with NO change in temperature is called the latent heat of
1. fusion
2. combustion
3. condensation
4. vaporization

4-31. If water is being heated and the number of molecules of steam returning to the liquid state is the same as the number changing from the liquid state to the gaseous state, this condition is known as
1. dry steam
2. condensation
3. vaporization
4. saturated vapor

Learning Objective: Relative to electricity, identify basic terms and principles, and recognize functions of various electrical components and electrical measuring instruments.

4-32. When a conductor cuts the lines of force of a magnet, the current produced in the conductor is known as magnetic
1. reluctance
2. induction
3. resistance
4. reaction

4-33. Refer to figure 4-18 in your textbook. Magnetic lines of force which exist around a bar magnet flow from the
1. axis to the south pole
2. north pole to the axis
3. north pole to the south pole
4. south pole to the north pole

4-34. In an automobile generator, the principle of magnetic induction is used to produce the electricity required to perform all but which of the following functions?
1. Operate the electrical system
2. Fire the spark plugs
3. Charge the battery
4. Dry the distributor

4-35. Which component of a generator produces the current?
1. The brushes
2. The armature
3. The commutator
4. The electromagnet

4-36. A generator having a split ring commutator delivers what type of current?
1. Steady direct current
2. Steady alternating current
3. Pulsating direct current
4. One-third alternating current

4-37. A lead-acid battery produces an electrical current by means of
1. magnetic induction
2. chemical action
3. mechanical action
4. static action

4-38. Displacement of what parts of the copper atoms in a copper wire causes an electric current to flow through the wire?
1. Protons
2. Neutrons
3. Electrons
4. Nucleus

4-39. The protons of the atoms of copper do NOT move to other atoms as do the electron atoms of copper because the protons are how many times heavier than the electrons?
1. 1,850 times
2. 1,860 times
3. 2,000 times
4. 2,850 times

4-40. The direction of flow of electrons from a voltage source, through a conductor, and back to the voltage source is from
1. positive to positive
2. positive to negative
3. negative to positive
4. negative to negative

4-41. An insulator is characterized by its scarcity of
1. protons
2. neutrons
3. free electrons
4. governor electrons

4-42. What is another designation for voltage?
1. Amperage
2. Quantity of electrons
3. Conductivity of matter
4. Electromotive force

In items 4-43 through 4-45, select from column B the function of each basic electrical measuring instrument listed in column A.

A. Measuring Instruments	B. Functions
4-43. Voltmeter	1. To measure the resistance of a conductor to the flow of electricity through it
4-44. Ammeter	2. To measure the electromotive force produced by a battery or generator
4-45. Ohmmeter	3. To measure the amount of work being done by a circuit
	4. To measure the number of electrons of the conductor flowing past a given point each second

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Learning Objective: Relative to publications and the Naval Aeronautic Publications Index, indicate the issuing authority, method of updating, contents, numbering system, and procurement.

4-46. Aeronautic publications that deal with operations and maintenance of support equipment are issued by authority of the
1. Chief of Naval Operations
2. Secretary of the Navy
3. Deputy Chief of Naval Operations
4. Naval Air Systems Command

4-47. When they are available for issue, manuals and letter materials are assigned code numbers and are listed in the publications entitled
1. Navy-Air Force Publications Index
2. Naval Aeronautic Publications Index
3. Navy-Air Force Publications Instruction
4. Naval Aeronautic Publications Instruction

4-48. In determining if a manual-type publication is the latest issued, the ASM may refer to
1. NAVAIR 00-500A
2. NAVAIR 00-500B
3. NAVAIR 00-500C
4. NAVSUP 2002

4-49. Which of the following are contained in Section III of the NAVSUP 2002?
1. Instructions and Notices
2. Manual-type publications
3. Technical directives
4. All forms used by the Navy

● Refer to table 5-1 and figure 5-1 in answering items 50 through 52.

4-50. What is the subject classification of the publication NA-01-45HHC-2-1?
1. General
2. Aircraft
3. Powerplants
4. Accessories

4-51. What is the general subject classification number for Ground Servicing and Automotive Equipment?
1. 11
2. 12
3. 16
4. 19

4-52. The subject classification of publications in group 17 is
1. general
2. powerplants
3. accessories
4. machinery, tools, and test equipment

4-53. The listing of manuals that are available on specific items of aeronautic equipment is found in which of the following?
1. Aircraft Application List, NAVAIR 00-500B
2. Directives Application List, NAVAIR 00-500C
3. Equipment Applicability List, NAVAIR 00-500A
4. Navy Stock List of Forms and Publications, NAVSUP 2002

4-54. A cross-reference listing of manuals according to model-type part number is found in the
1. Navy Stock List of Forms and Publications, NAVSUP 2002
2. Equipment Applicability List, NAVAIR 00-500A
3. Aircraft Application List, NAVAIR 00-500B
4. Directives Application List, NAVAIR 00-500C

4-55. A listing of NAVAIRSYSCOM letter-type directives is found in
1. NAVAIR 00-500A
2. NAVAIR 00-500B
3. NAVAIR 00-500C
4. NAVAIR 00-500D

4-56. The NAVAIR 00-500M is divided into how many parts?
1. One
2. Two
3. Three
4. Four

4-57. How is NAVAIR 00-500B kept current?
1. By annual reissue with no supplements
2. By semiannual reissue with monthly supplements
3. By letter-type directives, as occurring
4. By bimonthly addendums

4-58. How is the NAVAIR 00-500M kept current?
1. By annual reissue with bimonthly revision
2. By annual reissue with no revisions
3. By semiannual addendums
4. By semiannual reissue with no revisions

Learning Objective: Identify methods for numbering both manual and letter-type publications and recognize what is indicated by various parts of the manual classification code.

4-59. What prefix is assigned to publications originated by the Naval Air Systems Command?
1. Air Force Navy (AN)
2. NAVAER (NA)
3. NAVAIR (NA)
4. NAVWEPS (NW)

4-60. Refer to figure 5-2. The -110A of the publication number NA-19-110A-4 indicates the
1. type of manual
2. type of aircraft
3. section number of the manual
4. particular group of equipment

4-61. Refer to table 5-2. Which code number in the manual-type publications identifies the subject breakdown pertaining to aircraft hydraulic jacks?
1. 19-10
2. 19-20
3. 19-70
4. 19-80

4-62. Refer to table 5-1. Part III of the manual-type publications code number designates which of the following?
1. A particular group
2. A specific manufacturer
3. A specific manual
4. A general manual

4-63. How are letter-type publications changes numbered that relate to all support equipment?

1. By Julian date
2. By calendar date
3. In number sequence
4. In alphanumeric sequence

4-64. What method of numbering letter-type directives covers all Instructions and Notices?

1. Consecutively from the beginning of the fiscal year
2. Consecutively according to subject matter
3. Consecutively from the beginning of the calendar year
4. Alphanumerically in accordance with aircraft application

Assignment 5

Publications, MIARS, and Drawings; Reciprocating Combustion Engines

Text: Pages 128 - 155

Learning Objective: Identify the regulation governing security of classified publications, how classified publications are identified in the Numerical Index, and procedures relating to the reissue and the one-time issue of aeronautical publications.

5-1. The Department of the Navy Information Security Program Regulation, OPNAV Instruction 5510.1 (Series), is issued by
1. SECNAV
2. CNO
3. DOD
4. NAVAIRSYSCOM

5-2. The provisions of OPNAV 5510.1 (Series) apply to
1. civilian personnel only
2. enlisted personnel only
3. officer personnel only
4. every person and every activity in the Naval Establishment

5-3. Which numeral in the SC (security classification) column of the Numerical Index indicates that a NAVSUP 2002 publication is classified?
1. One
2. Two
3. Three
4. Four

5-4. After a Mailing List Request for Aeronautic Publications, NAVAIR Form 5606/3, has been properly completed for the reissue of an existing publication, the form should be submitted to the
1. Naval Air Systems Command
2. Naval Air Technical Service Facility
3. Forms and Publications Supply Office
4. nearest Aeronautic Publications Supply Point listed in the Naval Aeronautic Publications Index

5-5. If the commanding officer of an aviation support activity uses a DD Form 1348 to order publications directly from the Naval Air Technical Service Facility (NATSF), what is he requisitioning?
1. Initial outfitting publications
2. Specific publications to be added for automatic distribution
3. All automatic distribution publications
4. One-time requirement publications

Learning Objective: With respect to manual-type publications important to the ASM, recognize their series, contents, preparation and issuing authority, numbering system, and procedures for incorporating changes.

5-6. Which of the manual-type publications series shown in table 5-1 are of special importance to the ASM?
1. 00, 17, and 19
2. 00, 02, and 17
3. 01, 02, and 19
4. 02, 03, and 17

5-7. Allowance Lists are included in what series of publications in the Naval Aeronautic Publications Index?
1. 00
2. 03
3. 17
4. 19

5-8. Which section of the Allowance Lists and Outfitting Lists (00-35 Series) includes the allowance of general support equipment?
1. B
2. G
3. H
4. K

5-9. In Allowance List number 00-35QZ-40, the Z identifies the
1. section of an Allowance List series
2. series in an Allowance List section
3. Allowance List section
4. issuing authority

5-10. After the support equipment manuals are prepared by the manufacturer, who has the authority to issue them?
1. The Naval Ship Systems Command
2. The Naval Air Systems Command
3. The Naval Supply Systems Command
4. The Naval Weapons Command

5-11. Which section of the Operation and Service Instructions Manuals will most likely contain information on the specifications of support equipment cooling systems?
1. Introduction
2. Description of the Equipment
3. Preparation for Use
4. Operation Instructions

5-12. Which of the following is NOT included in the Operation Instructions of the Operation and Service Instructions Manual for an item of support equipment?
1. The principles of operation
2. The preparation of the unit for use
3. The purpose and use of the operating controls
4. The purpose and use of the indicating instruments

5-13. Manuals that are labeled Repair or Overhaul Instructions are usually issued for which of the support equipment maintenance levels?
1. Organizational only
2. Intermediate only
3. Depot
4. Organizational or Intermediate

5-14. The publication that is designed to aid maintenance personnel in identifying and ordering replacement parts is the
1. Overhaul Instruction Manual
2. Service Instruction Manual
3. Illustrated Parts Breakdown (IPB)
4. Maintenance Instructions Manual

5-15. In the Illustrated Parts Breakdown, information designed to aid the ASM in quickly and easily locating illustrations, descriptions, and numbers of the parts he needs is found in the
1. Introduction
2. Group Assembly Parts List section
3. Numerical Index section
4. Table of Contents

In items 5-16 through 5-18, select from column B the manual in which each item of maintenance information listed in column A is found.

	A. Information	B. Manuals
5-16.	The intervals between complete disassembly for component inspection	1. Operation and Service Instruction
5-17.	A cross-reference for determining a part number if the part is known, or the part description if the part number is not known	2. Repair or Overhaul Instruction
		3. Illustrated Parts Breakdown
5-18.	Necessary inspections and adjustments during operational period	4. NATOPS

5-19. What determines the degree of urgency for updating technical publications?
1. The number of technical data changes that accumulate pertaining to the affected publication
2. The type of information involved and the frequency of reference to the affected publication
3. The number of maintenance personnel using the affected publication
4. The date of the last change recorded in the affected publication

5-20. Changes to publications that are held by production divisions are incorporated into the publications by personnel of the
1. administration division
2. technical library staff
3. quality assurance division
4. respective work centers

5-21. If an ASM in a work center files a page of technical information next to an affected page in the publication, what type of change is he incorporating?
1. Write-in
2. Replacement
3. Supplement data
4. Duplicate change

5-22. Which of the following statements is correct of supplementary page 5-65A and the information thereon?
1. It is placed between pages 5-65 and 5-66, and may apply to either of those pages, but not to both
2. It is placed between pages 5-65 and 5-66, and may apply to either or both of those pages
3. It is placed after page 5-64, and applies only to page 5-65
4. It is placed between pages 5-65 and 5-66, and applies only to page 5-65

5-23. Where is the issue date of a replacement page in a manual noted?
1. On the back of the manual's cover page
2. On the bottom of the replacement page
3. On the back of the replacement page
4. On the front of the manual's cover page

Learning Objective: Identify types, contents, purposes, and procedures associated with letter-type and miscellaneous aviation publications.

5-24. When it is NOT feasible to issue a revision to a manual, the technical instructions therein are updated by means of a
1. Change or Bulletin
2. Notice or Technical Order
3. Technical Note or Change
4. Bulletin or Notice

5-25. What type of technical directive is disseminated by means of a message?
1. Notice
2. Interim Change or Bulletin
3. Technical Note
4. Technical Order

5-26. Of the following directives, the one that would be classified as a Bulletin is the one which contains instructions and directions to
1. install a specified workstand component
2. correct a safety or operational condition
3. perform tests on a specified fuel system component
4. modify the parts of a specified ignition system

5-27. Which type of directive is identified as a completely new edition of an existing directive?
1. Amendment
2. Reissue
3. Revision
4. Change

5-28. An Interim Directive pertaining to a system that is NOT in use on an equipment has the type of action printed at the top of the cover page and a border of Xs around the cover page. The time limit for compliance is
1. within 120 days of the date of issue
2. prior to the next use of the system
3. no later than the next scheduled overhaul
4. no later than the next periodic inspection

5-29. Refer to table 5-3 in your textbook. If an interim directive labeled URGENT ACTION pertains to support equipment which involves the use of affected components in an ignition system, what is the time limit for compliance?
1. Within 60 days of the date of issue
2. No later than the next overhaul
3. No later than the next periodic inspection
4. Prior to the next use of the ignition system

5-30. Directives containing information concerning policy, administration, and air operations that are applicable for only a brief period of time are called
1. Specifications
2. Instructions
3. Bulletins
4. Notices

5-31. If an ASM wants to obtain the most accurate current information on the subject of accident prevention, what should he read?
1. Approach
2. Naval Aviation News
3. The applicable Crossfeeds
4. MECH

Learning Objective: Identify how the Maintenance Information Automated Retrieval System functions.

5-32. The delay between the time a technical manual change is issued and the time that change is translated into a repair action is known to the ASM as
1. warning time
2. damage time
3. lagging time
4. safety time

5-33. The MIARS is a program implemented by
1. SECNAV
2. CNO
3. NAVAIRSYSCOM
4. NAVSUPSYSCOM

5-34. Refer to table 5-4. A film cartridge with a number of SE2.399 is applicable to what level of maintenance?
1. Organizational
2. Depot only
3. Depot and Intermediate
4. Intermediate only

Learning Objective: Indicate functions of drawings developed to facilitate equipment maintenance, and recognize the use and application of related symbols, codes, and publications.

In items 5-35 through 5-38, select from column B the type of illustration applicable to each use listed in column A.

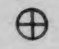
	A. Uses	B. Illustrations
5-35.	To present construction detail that is not clearly shown by other illustrations	1. Pictorial
		2. Dimension
		3. Cutaway
5-36.	To show actual size or distance measurements	4. Assembly
5-37.	To show what a unit actually looks like	
5-38.	To show how parts of a unit are put together to form the unit	

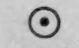
5-39. A block diagram serves to show the
1. overall functional operation of a system
2. physical shape of a component
3. physical size of a component
4. physical location of a component

● Refer to figure 5-7 in answering items 5-40 and 5-41.

5-40. Which geometric symbol is used to denote true position in locating an object on a drawing?

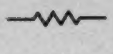
1.

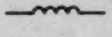
2. 

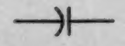
3. 

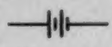
4.

5-41. Which electronics symbol represents a battery?

1. 

2. 

3. 

4. 

5-42. Which type of wiring diagram would you use to obtain the greatest detail to aid you in the testing and maintenance of the wiring on a piece of support equipment?
1. System
2. Section
3. Circuit
4. Component

5-43. On an isometric drawing, a shielded 6-wire interconnecting cable is represented by how many lines?
1. One
2. Two
3. Six
4. Seven

5-44. To facilitate maintenance, which source of information should be consulted when deciphering the code on a wire or cable given in a chassis diagram?
1. The construction diagram
2. The chassis diagram
3. The maintenance manual for the given piece of equipment
4. The latest revision of MIL-W-5088C

5-45. In figure 5-8 the unit number and circuit function designators show that the wire is used for
1. general-purpose installation and it is the second of only two identical installations
2. either ac or dc power and another identically installed unit uses the alternate power
3. dc power and there is at least one more identically installed unit in the same equipment
4. ac power and there is at least one more identically installed unit in the same equipment

5-46. Usually, the stated size of tubing indicates the
1. outside diameter
2. length of the unit run
3. pressure-carrying capability
4. inside diameter

5-47. Why are symbols used in line identification?
1. So that secondary functions may be indicated in minimum space
2. So that lengthy words or phrases will not have to be imprinted
3. So that line construction characteristics may be indicated in addition to functional descriptions
4. So that non-English-speaking people and colorblind people can identify the line functions

5-48. Refer to figure 5-9 in your textbook. What is carried in a line identified by green tape upon which horizontal rectangles are printed?
1. Rocket oxidizer
2. Rocket catalyst
3. Inerting gas
4. Breathing oxygen

5-49. What letters are printed on the tape around a gasoline line?
1. PHDAN
2. TOXIC
3. FLAM
4. AAHM

5-50. Refer to table 5-5 in your textbook. Which of the following fluids would all have "PHDAN" marked on the lines carrying them?
1. Carbon dioxide, gaseous oxygen, liquid oxygen (LOX), and JP-4
2. Freon, liquid nitrogen, and Trichlorethylene
3. Carbon dioxide, liquid nitrogen, Freon, and liquid oxygen (LOX)
4. Carbon dioxide, nitrogen gas, alcohol, and Freon

Learning Objective: Recognize operating principles, terms, and physical properties associated with internal combustion engines, and identify and utilize formulas for calculating horsepower, piston displacement, and compression ratio.

5-51. An internal combustion engine is a machine that converts energy from one form to another, and the conversion that takes place is a change of
1. mechanical energy to heat energy
2. chemical energy to heat energy
3. heat energy to chemical energy
4. heat energy to mechanical energy

5-52. Internal combustion engines need three essentials in order to operate. Which of the following is NOT one of these essentials?
1. Air
2. Water
3. Fuel
4. Ignition

In items 5-53 through 5-56, select from column B the definition of each term in column A.

	A. Terms	B. Definitions
5-53.	Work	1. The ability to do work
5-54.	Energy	2. The rate at which work is accomplished
5-55.	Power	3. The movement of an object against an opposing force
5-56.	Friction	4. The resistance to motion between two objects that are in contact with each other

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5-57. If it takes a person using a hoist 30 seconds to raise a 264-pound engine block 10 feet, approximately how much horsepower is developed?
1. 0.16 hp
2. 0.32 hp
3. 1.60 hp
4. 3.20 hp

5-58. What property of matter causes an object to remain at rest or in uniform motion in the same straight line unless acted upon by some external force?
1. Resistance
2. Gravity
3. Inertia
4. Kinetics

5-59. Which of the following is the correct mathematical manipulation for determining the efficiency of an internal combustion engine?
1. Divide the brake horsepower into the indicated horsepower
2. Divide the indicated horsepower into the brake horsepower
3. Subtract the brake horsepower from the indicated horsepower
4. Subtract the indicated horsepower from the brake horsepower

5-60. Using 3.14 to represent π, what is the approximate displacement of a piston with a 2.0-inch bore and a 4.25-inch stroke?
1. 6.72 in^3
2. 13.35 in^3
3. 26.70 in^3
4. 53.40 in^3

5-61. What is the approximate compression ratio of the piston in the preceding item if the volume of the combustion chamber is 1.335 in^3?
1. 4 to 1
2. 6 to 1
3. 8 to 1
4. 10 to 1

Learning Objective: Identify the basic operating principles of the two-stroke cycle and four-stroke cycle internal combustion engines.

Refer to figure 6-4 in your textbook in answering items 5-62 through 5-65. Select from column B the valve action associated with each stroke of a four-stroke cycle engine listed in column A.

	A. Strokes	B. Valve Actions
5-62.	Intake	1. Both valves open
5-63.	Compression	2. Both valves closed
5-64.	Power	3. Exhaust valve open and intake valve closed
5-65.	Exhaust	
		4. Intake valve open and exhaust valve closed

5-66. In a two-stroke cycle engine, every down stroke is a
1. power stroke
2. intake stroke
3. exhaust stroke
4. compression stroke

Assignment 6

Reciprocating Combustion Engines

Text: Pages 157 - 189

Learning Objective: Identify the major components and associated parts of the internal combustion engine, their purposes, operating and design characteristics, and applicable preventive and corrective maintenance procedures.

6-1. That component of the internal combustion engine that is considered the basic engine frame upon which all accessories are attached is the
1. head
2. block
3. manifold
4. crankcase

6-2. Wet liners and dry liners, which are either slip fit or press fit, refer to
1. the inner surfaces of all cylinders
2. all gasoline cylinder walls
3. wear-resistant, metal alloy, replaceable cylinder walls
4. the inner surfaces of the liquid cooling system next to the cylinder walls

6-3. If it is determined that corrective maintenance action to an engine is necessary due to excessive wear on the sides of a cylinder wall, which of the following would indicate the most probable solution?
1. Rebore the cylinder
2. Replace the engine block
3. Install oversized rings on the old piston to take up the slack created by wear
4. Install oversize pistons with old rings

6-4. The piston in an internal combustion engine is used to
1. dissipate the heat of combustion
2. prevent combustion energy from affecting the crankshaft motion
3. transfer the force of combustion to the connecting rod
4. transfer the force of combustion to the cylinder wall

6-5. What is the correct order, from top to bottom, in which compression and oil regulating rings should be placed on a piston with four ring grooves?
1. Compression, oil regulating, compression, oil regulating
2. Oil regulating, compression, compression, oil regulating
3. Compression, oil regulating, oil regulating, compression
4. Compression, compression, oil regulating, oil regulating

6-6. Refer to figure 6-7 in your textbook. The cylindrical surface on the bottom portion of the piston is referred to as the
1. land
2. boss
3. skirt
4. head

6-7. Approximately what percent of the heat of combustion that is absorbed by the piston is transmitted to the cylinder walls by the piston rings?
1. 15 percent
2. 33 percent
3. 50 percent
4. 67 percent

6-8. The main purpose of the piston and piston rings combination is to
1. transfer the heat of combustion to the cylinder walls
2. provide a seal below the cylinder combustion chamber
3. guide the upper end of the connecting rod
4. scrape oil from the cylinder walls and return it to the crankcase

6-9. When a new piston assembly is installed in an internal combustion engine, which of the following is necessary before the piston assembly can be inserted into the cylinder?
1. The unit must be balanced
2. The rings must be spread apart
3. The rings must be compressed
4. The unit must be attached to the crankshaft

6-10. Most of the maintenance accomplished on connecting rods involves replacement of the
1. twisted rods
2. broken rods
3. bearings or bearing inserts
4. wrist pins

6-11. The crankshaft changes the motion of the pistons and connecting rods to what type of motion?
1. Rotary
2. Relative
3. Up and down
4. Back and forth

6-12. The part of the crankshaft where the connecting rod is fastened is offset to give thrust to the shaft and is called the
1. throw
2. speed handle
3. brace
4. crank

6-13. How many revolutions does a crankshaft make for each power stroke of the piston in a four-stroke cycle engine?
1. One
2. Two
3. Three
4. Four

6-14. How is the torsional vibration of a crankshaft controlled?
1. By regulating the shaft's rotational speed
2. By installing shorter connecting rods
3. By installing a damper on the front of the crankshaft
4. By installing a damper on the rear of the crankshaft

6-15. The camshaft timing gear, operated by the crankshaft gear, directly operates all but which one of the following?
1. Fuel pump
2. Water pump
3. Valve mechanism
4. Ignition distributor

6-16. Which of the following statements concerning a flywheel on an internal combustion engine is correct?
1. Its ring gear is meshed with the camshaft gear
2. It stores energy and helps torsional vibration
3. It is connected to the starter drive gear by a chain
4. A relatively large one is required for an 8-cylinder engine while a small one will suffice for a 2-cylinder engine

6-17. How many valves does a standard 8-cylinder engine have?
1. 24
2. 16
3. 8
4. 4

6-18. Refer to figure 6-14 in your textbook. Why are valve seats made angular rather than flat?
1. To provide greater contact surface
2. To reduce carbon buildup on the seating surface
3. To lower the valve into the head or block
4. To prevent accumulation of carbon in the valve guide

6-19. What is the first operation you should perform in reconditioning valves after their removal?
1. Grind them and their seats
2. Clean the carbon off with a wire brush or buffing wheel
3. Service the guides and replace them if necessary
4. Install new seat inserts

6-20. Valve guide wear can be checked by using a/an
1. inside micrometer
2. a hole gage and micrometer to determine the relative sizes of the guide and the valve stem
3. a tensiometer to measure the force necessary to lift the valve
4. feeler gage

6-21. After the valves have been removed, inspection reveals that the replaceable-type valve guides are badly worn. Proper servicing requires that
1. valves with standard oversize stems be installed
2. the guides be reamed and the original valves reinstalled
3. the guides be reamed to a larger size and new valves with oversized stems be installed
4. the guides be replaced with new ones

6-22. Which type of stone should you use to recondition a valve seat contact that is too wide and low as shown in figure 6-15 in your textbook?
1. A soft seat stone
2. A finishing stone
3. A hard seat stone
4. A 20° narrowing stone

6-23. What will be the result if valves are adjusted with too little clearance between them and the rocker arms or mechanical lifters?
1. The valves will open late
2. The valves will not open far enough
3. The valves will overheat and warp
4. The valves will cause the engine to operate too cold

6-24. Valves in the block are adjusted when the position of the piston is
1. top dead center (TDC) on the compression stroke
2. top dead center (TDC) on the exhaust storke
3. bottom dead center (BDC) on the power stroke
4. bottom dead center (BDC) on the intake stroke

6-25. Hydraulic valve lifters provide ideal valve timing because they
1. operate with zero clearance only
2. compensate for changes in engine temperature only
3. compensate for minor wear at various points within the lifter only
4. operate with zero clearance and compensate for changes in engine temperature and for minor wear within the lifter

6-26. If a clicking noise is heard in an engine, this would be caused by a faulty
1. lifter
2. ring
3. wrist pin
4. timing chain

6-27. If the plunger of a hydraulic valve lifter is found to be faulty, proper servicing requires replacement of the
1. plunger
2. plunger and the inertia valve
3. plunger, inertia valve, and the check ball
4. entire valve lifter unit

6-28. Which of the following are not contained within the cylinder heads of V8, overhead valve, internal combustion engines?
1. Combustion chamber indentations
2. Threaded openings for spark plugs
3. Parts of the valve operating mechanisms
4. Parts of the exaust and intake manifolds

6-29. What part of the engine must be removed to inspect the crankshaft, camshaft, and connecting rods?
1. Oil cover
2. Oil pan
3. Exhaust manifold
4. Cylinder head

Learning Objective: Relative to internal combustion engine cooling systems, identify the purpose, operating principles, components, and troubleshooting and maintenance problems and techniques.

6-30. The cooling system, whether of the air or liquid type, is specifically designed to keep the internal combustion engine operating at what temperature?
1. Approximately 400° F
2. Approximately 500° F
3. At its most efficient operating temperature
4. At the temperature at which the lubricating oils are most efficient

6-31. In an air cooled engine, what systems are designed to help keep the engine cool?
1. Fuel and lubrication systems
2. Fuel and water coolant systems
3. Lubrication and water coolant systems
4. Water coolant and air-flow systems

6-32. Proper maintenance of an air cooled engine's cooling system does NOT encompass which of the following maintenance procedures?
1. Keeping baffles, fins, shrouds, and fans free of dirt, grease, and foreign matter
2. Periodic inspection and tightening of shrouds, baffles, and defelectors
3. Replacing or straightening broken or bent parts
4. Replacing or straightening broken or bent parts

● Items 6-33 through 6-53 refer to liquid cooling systems.

6-33. Which of the following represents the sequence of the flow of coolant through an internal combustion engine?

1. Pump → cylinder head → radiator → cylinder block → pump
2. Pump → cylinder block → cylinder head → radiator → pump
3. Pump → cylinder head → cylinder block → radiator → pump
4. Pump → radiator → cylinder head → cylinder block → pump

6-34. That section of the system which permits the heat generated within an operating internal combustion engine to be conducted into the coolant and to be dissipated later in the circulation process is called the

1. radiator
2. water jacket
3. coolant jacket
4. cylinder block passages

6-35. What is the action of the water pump in the liquid cooling system?

1. With force it circulates water from the top of the radiator to the bottom of the radiator
2. With force it circulates water from the bottom of the radiator to the top of the radiator
3. With force it applies power to the fan forcing it to increase air flow across the engine
4. It regulates the flow of coolant in the cooling system

6-36. Why is a water pump's moving shaft a likely place for a cooling system leak?

1. Because the impeller is submerged within the coolant
2. Because the power source is external to the cooling system
3. Because the impeller shaft is mounted on one or more ball bearings which require outside lubrication
4. Because the pump housing is a unit within itself and is removable from the block

6-37. The purpose of a fan shroud is to

1. provide a safety guard around the moving fan blades
2. assure that all of the air pulled back by the fan is directed over the engine assembly
3. improve the efficiency of the engine
4. stablize the mounting of the radiator

6-38. What is the purpose of the radiator in the system?

1. To provide a reservoir for the coolant
2. To divide the coolant into many small streams
3. To transfer heat from the coolant to the air moving through it
4. To break up the air pulled by the fan into many small streams

6-39. Why is a radiator pressure cap used?

1. For faster circulation, hence more efficient cooling
2. For slower circulation, hence more efficient cooling
3. For high engine operating temperatures without coolant loss
4. For low engine operating temperatures without coolant loss

6-40. How many valves are normally in the pressure radiator cap?

1. One
2. Two
3. Three
4. Four

6-41. The system's thermostat is activated by

1. pressure
2. expansion
3. contraction
4. temperature

6-42. What is the normal position of a properly-functioning thermostat when the engine is at operating temperature?

1. Completely open
2. Completely closed
3. Half open
4. Three-fourths open

6-43. The engine units of the temperature gages of both the Bourdon tube and the electric types are installed so that they detect the temperature of the

1. lubricating oil
2. coolant
3. metal of the block
4. exhaust manifold

6-44. How, if at all, can a damaged temperature gage with a Bourdon tube be repaired?

1. With a soldering iron
2. It cannot be repaired
3. By pinching the tube
4. By sending the unit to overhaul

6-45. When antifreeze is used, frequent checking for leaks is necessary because antifreeze
1. makes the water less viscous
2. evaporates easily
3. corrodes or rusts the cooling system
4. penetrates openings and connections more readily than water

6-46. In testing antifreeze solutions, a hydrometer measures the solution's
1. density
2. specific gravity
3. freezing temperature
4. content of antifreeze compared to that of water

6-47. A foaming action causing some loss of coolant solution from an operating engine's cooling system may result if
1. there is air in the system
2. different types of antifreeze are mixed together
3. the percentage of antifreeze in the solution is too great
4. there is rust in the radiator

6-48. In the absence of pertinent instructions, cooling systems should be flushed and cleaned at least
1. every quarter
2. twice a year
3. at every maintenance inspection
4. once a year

6-49. What is the first step taken in flushing the cooling system?
1. Add more water
2. Drain all the water
3. Add rust cleaning compound
4. Run the engine for thirty minutes

6-50. Which of the following may cause an operating engine to run either too cool or too hot?
1. A malfunctioning thermostat
2. A defective pressure cap
3. A collapsed water hose
4. A slipping fan belt

It items 6-51 through 6-53, select from column B the appropriate test procedure for each cooling system problem listed in column A.

	A. Problems		B. Test Procedures
6-51.	Air leak	1.	Disconnect the upper hose, remove the fan belt and thermostat, start the engine and observe the coolant's reaction
6-52.	Water pump inefficiency	2.	With the engine warm and running, squeeze the upper radiator hose to determine if pressure is present
6-53.	Exhaust gas leakage into the system	3.	Push in on the belt midway between the pulleys to check its tension
		4.	Attach a hose to the overflow pipe and place the other end in a bucket of water and check for bubbles

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Learning Objective: Relative to an internal combustion engine's lubrication system and system components, identify functions, ventilation and circulation principles, and maintenance problems and techniques.

6-54. Which of the following is the primary function of an engine's lubrication system?
1. To prevent metal-to-metal contact
2. To aid in cooling the engine
3. To help keep the engine parts clean
4. To act as a shock absorbing agent

6-55. What two types of oil pumps are normally used in the lubricating system?
1. Gear and piston
2. Gear and rotary
3. Rotary and piston
4. Rotary and vane

6-56. What is the function of the oil pressure gage in the lubrication system of an internal combustion engine?
1. To show the oil level in the oil pan
2. To maintain proper oil pressure in the system
3. To ensure that 30 to 50 psi are produced by the oil pump
4. To indicate the efficiency of the oil system

6-57. A spring-loaded valve which opens to allow oil to pass around a clogged filter is incorporated in which of the following types of oil filters?
1. Bypass
2. Full flow
3. Strainer
4. Enclosed

6-58. In which of the engine crankcase ventilation methods are the gasoline vapors recirculated back through the intake manifold?
1. Positive only
2. Nonpositive only
3. Positive and nopositive
4. Either positive or nonpositive depending on the presence of a breather tube

6-59. As the oil leaves the regulator it is cooled or heated depending upon the temperature of the
1. water in the cooling system
2. outside temperature of the air
3. electrical heating coil
4. glow plugs

In items 6-60 through 6-62, select from column B the method by which each type of oil lubrication system listed in column A circulates oil.

A. Systems	B. Circulation Methods
6-60. Splash	1. Oil is circulated through lines and channels in the crankshaft and connecting rods by a pump, and the cylinders are lubricated by oil thrown from the connecting rods
6-61. Force-feed	2. Oil is circulated under pressure from the pump to all moving engine parts
6-62. Full force-feed	3. Oil is circulated only by dippers on the connecting rods
	4. Oil is circulated by a pump to the main bearings and valves, while dippers on the connecting rods lubricate the cylinders by splashing oil

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6-63. Low oil pressure may be caused by
1. use of an improper grade of oil only
2. low oil level in the crankcase only
3. excessive heating of the engine only
4. use of the improper grade of oil, low oil level, or overheating engine

6-64. If you are installing an oil line and it becomes necessary to make a very sharp bend in the copper tubing, what should you use to make the bend?
1. Your hands
2. Two pipe wrenches
3. A tube bender
4. A strap wrench

6-65. To isolate the problem of persistently high oil pressure after the possibility of a clogged oil line has been eliminated, the ASM should next check the operation of the
1. oil filter element
2. oil temperature regulator
3. oil pressure gage assembly
4. oil pressure regulating valve

Assignment 7

Reciprocating Combustion Engines and Reciprocating Gasoline Engines

Text: Pages 189 - 219

Learning Objective: Recognize the speed and power regulating force of a gasoline engine and, relative to governors, indicate functions, types, and related selection requirements, and operating principles.

7-1. In a gasoline engine, speed and power output are controlled by regulating the
1. hotness of the spark in the cylinders
2. amount and velocity of the air flowing into the cylinders
3. amount of fuel injected into the cylinders
4. combustion chamber size

7-2. Which component prevents engine overspeeding by making allowances for varying power output demands?
1. The governor
2. The carburetor
3. The accelerator
4. The hand throttle

7-3. The kind of governor to be used on a diesel engine is determined by the
1. type of load on the engine and the degree of control desired
2. horsepower of the engine
3. grade of fuel used in the engine
4. maximum engine operating speed

7-4. In addition to being classified by speed regulation, governors on diesel engines may also be classified according to
1. functions performed only
2. the means by which they operate the fuel-control mechanism only
3. the forces used in operation only
4. functions performed, how the fuel control mechanism operates, and the forces used in operations

In items 7-5 through 7-7, select from column B the governor action that is performed by each type of governor listed in column A.

A. Governors	B. Actions
7-5. Load-limiting	1. Maintains any speed between idle and maximum speed
7-6. Variable-speed	2. Maintains the same speed regardless of the load
7-7. Speed-limiting	3. Keeps the engine from exceeding a specified maximum speed and from dropping below a specified minimum speed
	4. Limits the load the engines will handle at various speeds

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7-8. If a diesel engine is controlled by a spring-loaded centrifugal governor, what will be the effect on the speed of the engine if the centrifugal force becomes greater than the spring tension of the governor?
1. The engine will speed up
2. The engine will slow down
3. The engine will alternately speed up and slow down
4. The engine speed will remain the same

7-9. What will happen to an engine that has oil blow-by in the cylinders after the ignition is turned off?
1. Normal operation
2. Engine will disintegrate
3. Engine will shut down automatic
4. Engine will decrease its speed

7-10. The device that reduces excessive speed of an engine but still allows the engine to continue to run at a safe speed is called an overspeed
1. trip
2. cutout
3. governor
4. switch

Learning Objective: Identify inspection requirements, techniques, and materials applicable to aviation support equipment.

7-11. Other than an equipment's Periodic Maintenance Requirements Manual, what instructions list the requirements for periodic, daily, and special inspections?
1. Maintenance Requirement Cards
2. Maintenance Daily Cards
3. 4790.2A/50
4. 4790.2A/51

7-12. What method is generally employed to inspect certain metallic parts of equipment for nearly invisible cracks or defects?
1. Paint
2. Bright light
3. Penetrant
4. Sanding

7-13. As an alternative to the penetrant inspection, what type of inspection should be conducted on material which is magnetic?
1. Fluorescent dye
2. Visible dye
3. Magnetic particle
4. Nonporous material

7-14. What materials are contained in a fluorescent inspection kit?
1. Penetrant, dye remover, emulsifier, and developer
2. Penetrant, dye remover, emulsifier, developer, and bright light
3. Penetrant, penetrant cleaner, developer, and black light
4. Penetrant, Stoddard Solvent, developer, and black light

7-15. Which of the following is necessarily common to the Type I and Type II penetrant inspection processes but NOT to the Type III process?
1. Developer
2. Black light
3. Solvent base
4. Emulsifier

7-16. Of the following, which is considered the greatest asset to ensure accurate interpretation of the results of penetrant-type inspections?
1. Experience
2. Formal training
3. The ability to follow prescribed procedures
4. The ability to interpret technical data correctly

Learning Objective: Define troubleshooting, recognize ASM equipment safety precautions, and identify the authority for changes to equipment and operating procedures.

7-17. The definition of troubleshooting may be stated as
1. the performance of preventive maintenance inspections
2. an orderly process to segregate problem causes
3. the performance of daily inspections
4. the process of deduction and elimination

7-18. The ASM's work is potentially dangerous in that, unless he practices proper safety precautions, he could possibly be injured from
1. toxic fumes only
2. electric shock only
3. hot fluids and hot metals only
4. toxic fumes, electric shock, and hot fluids and metals

7-19. Modifications of existing equipment and revisions to established operating procedures are directed by orders and bulletins issued by the
1. work area supervisor
2. Naval Air Systems Command
3. intermediate maintenance activity
4. organizational maintenance activity

Learning Objective: Relative to gasoline engine starting systems and their components, recognize operating characteristics and a propable cause of malfunctions.

7-20. Which unit is considered as the central unit of the starting, ignition, and generator/alternator systems?
1. Regulator
2. Battery
3. Starter
4. Distributor

7-21. What is the approximate speed ratio of the starter rotor to the crankshaft?
1. 1 to 1
2. 5 to 1
3. 10 to 1
4. 20 to 1

7-22. Why is the starter pinion demeshed from the flywheel after the engine is started?
1. To keep wear on the flywheel and pinion to a minimum
2. To prevent overspeeding the starter
3. To reduce the noise level of the engine
4. To reduce drag on the engine

In items 7-23 through 7-25, select from column B the meshing mechanism described by each operational characteristic listed in column A.

A. Characteristics

7-23. As the starter rotates, the pinion is moved forward or backward by inertia to engage the flywheel

7-24. It provides complete and positive meshing of the pinion and flywheel before the starter rotates

7-25. As the starter rotates, spring-loaded steel rollers move back and forth between the shell and rotor to engage and disengage the pinion and flywheel

B. Meshing Mechanisms

1. Dyer drive
2. Bendix drive
3. Centrifugal
4. Overrunning clutch

7-26. When starting troubles are traced to the starting system, the cause of the malfunction will most often be the
1. flywheel teeth
2. starter armature windings
3. starter pinion and spring
4. battery

Learning Objective: Relative to battery ignition systems, recognize components and their functions, operating design characteristics, and associated terms.

7-27. Ignition of the fuel-air mixture in an engine cylinder may be accomplished by how many methods?
1. One
2. Two
3. Three
4. Four

7-28. The voltage required to force a spark across the spark plug gap is approximately
1. 10,000 v
2. 20,000 v
3. 30,000 v
4. 40,000 v

7-29. The electricity to the spark plugs is controlled by the
1. coil
2. distributor
3. camshaft
4. crankshaft

7-30. The battery ignition system consists of how many circuits?
1. One
2. Two
3. Three
4. Four

7-31. Current will flow through the primary circuit whenever the
1. ignition is turned on
2. distributor points are closed
3. distributor points are open
4. condensor is charged

7-32. One of the functions of the capacitor in a battery-ignition system is to
1. stop the flow of magnetic lines of flux when the points open
2. act as a safety gap for the secondary coil
3. allow a rapid collapse of the magnetic field in the primary
4. stop the flow of current through the secondary winding

7-33. The magnetic flux linking the primary and secondary windings of an induction coil is changed by the
1. cam
2. capacitor
3. distributor points
4. electrodes in the distributor cap

7-34. The term saturation period, when used in regard to an induction coil, is defined as the period of time
1. it takes for the magnetic field in the secondary windings to reach full strength
2. it takes for the magnetic field in the primary windings to reach full strength
3. current is flowing through the secondary windings
4. that the points are open

7-35. The purpose of the contact points and cam in the distributor is to

1. open the primary circuit, causing a spark to jump across the gap of a particular spark plug which is connected into the primary circuit by means of the distributor
2. open the secondary circuit, causing the magnetic field to collapse at maximum strength
3. open the primary circuit, causing the magnetic field to collapse at maximum strength
4. induce a high voltage in the primary winding, causing a brief, strong flow of current in the primary circuit

7-36. The purpose of a capacitor (condensor) in the primary circuit is to prevent arcing between the contact points at the time of

1. initial opening
2. closing
3. starting the engine
4. stopping the engine

7-37. What is the approximate voltage of the current across a spark plug gap?

1. 7,500 v
2. 10,000 v
3. 15,000 v
4. 25,000 v

7-38. The rotor functions to close the circuit and permit current to reach a spark plug each time the crankshaft rotates by how much?

1. One-fourth of a turn
2. One-half of a turn
3. One full turn
4. Two full turns

7-39. In a six-cylinder engine the cylinders and spark plugs are numbered consecutively from the front. The leads from the distributor are arranged to send high voltage to the spark plugs in which firing order?

1. 2-4-6-1-3-5
2. 1-3-5-2-4-6
3. 2-6-4-1-5-3
4. 1-5-3-6-2-4

7-40. For each revolution of the distributor shaft on a six cylinder engine, the points will open and close how many times?

1. Eight times
2. Six times
3. Four times
4. Two times

7-41. The vacuum-type spark advance mechanism is directly connected between the

1. carburetor and spark plugs
2. spark plugs and distributor
3. distributor and carburetor
4. distributor, spark plugs, and carburetor

7-42. As the engine speed increases, the spark is advanced by the

1. camshaft
2. coil
3. distributor
4. crankshaft timing gear

7-43. The only purpose for the magneto in the magneto ignition system is to provide electricity for

1. battery charging only
2. ignition only
3. battery charging and ignition
4. lighting

7-44. What limits the output of the conventional ignition system?

1. The length of time the contact points remain closed only
2. The amount of current in the primary circuit only
3. The size and rating of the battery
4. The lengths of time the contact points remain closed and the amount of current in the primary circuit

7-45. In addition to extending the periods between engine tuneups, which of the following advantages does the transistorized ignition system have over a conventional ignition system?

1. Extended breaker point life only
2. Higher available voltage at the spark plugs only
3. Extended spark plug life only
4. Extended breaker point and spark plug life and higher available voltage at the spark plugs

Learning Objective: Recognize common causes of ignition system troubles and procedures for identifying, correcting, or preventing these troubles, including assoicated terms and data.

7-46. What ignition troubles are most often caused by wear when the engine is operating?

1. Faulty capacitor
2. Faulty coil
3. Faulty generator
4. Faulty connections or broken wires

7-47. In troubleshooting the ignition system, how many check points can be visual inspected before making any test?
1. Seven
2. Six
3. Three
4. Five

7-48. If the coil is connected so that polarity is reversed, what increase in voltage is required to fire the plugs?
1. 10 percent
2. 20 percent
3. 30 percent
4. 40 percent

7-49. In the distributor cap, high voltage jumping from the rotor to the terminal post will cause
1. heavy carbon deposits
2. mild scaling
3. mildew
4. hard starting

7-50. What is the correct color for normal ignition points?
1. Bright silver
2. Bright gray
3. Dull, slate gray
4. Bright, slate gray

7-51. What is the best method for repairing points that are burned or pitted?
1. Replace
2. File
3. Regap
4. Reset the regulator

7-52. With the secondary coil lead held approximately 3/16-inch from ground and the engine being cranked, a bright blue spark is observed. This indicates that troubleshooting can be limited to the
1. breaker points, coil, rotor, spark plug leads, and coil lead
2. distributor cap, rotor, spark plug leads, and spark plugs
3. distributor cap, coil, ignition resistor, and spark plugs
4. ignition resistor, breaker points, rotor, and coil

7-53. Refer to figure 7-10(A). With a voltmeter connected as shown, a battery-to-coil test is performed and a drop of 2.5 volts is obtained. What does this indicate?
1. A shorted coil primary winding
2. A shorted ignition resistor
3. An open ignition resistor
4. Proper operation

7-54. What test equipment is used to test spark plug leads for cracks or opens?
1. A multimeter
2. A voltmeter
3. An ammeter
4. A megger

7-55. What does a condenser of INCORRECT capacity cause?
1. Heavy arcing across the breaker points and metal transfer from one contact of the breaker points to the other
2. Heavy arcing across the breaker points and secondary coil failure
3. Metal transfer from one contact to the other of the breaker points and secondary coil failure
4. Primary coil failure

7-56. When maintenance on an ignition system is preferred, when does the procedure call for replacing the capacitor?
1. When the capacitor appears burned
2. When the points are replaced
3. When the points are burned
4. When so indicated on the preventive maintenance schedule

7-57. Improper alignment of contact points will result in
1. point bounce
2. rapid burning of the points
3. point chatter
4. low voltage at the spark plugs

7-58. What effect does excessive breaker point gap have on the ignition system?
1. Extended saturation time for the coil, and low speed missing
2. Reduced saturation time for the coil, and high speed missing
3. Extended saturation time for the coil, and high speed missing
4. Reduced saturation time for the coil, and low speed missing

7-59. Which of the following statements defines dwell?
1. The distance, in degrees of crankshaft rotation, that the breaker turns from the time the points close until they open
2. The distance, in degrees of breaker cam rotation, that the breaker cam turns from time the points open until they close
3. The distance, in degrees of engine cam rotation, that the engine cam turns from the time the points open until they close
4. The distance, in degrees of breaker cam rotation, that the breaker cam turns from the time the points close until they open

7-60. Refer to figure 7-14. Which of the following statments is correct regarding the relationship between dwell and point gap?

1. They are the same
2. They are indirectly proportional
3. They are directly proportional
4. They are not related

7-61. Why must engine oil or low temperature grease NOT be used to lubricate the breaker cam?

1. Only special oil is specified
2. It will be thrown off and onto the points
3. It causes rapid deterioration of the point rubbing block
4. The felt wick will not hold it

7-62. A distributor is being installed and it will NOT bottom. What must be done?

1. Remove the distributor and turn the shaft one tooth
2. Install the holddown bolt and pull the distributor down
3. Hold firm pressure on the distributor and crank the engine to align the oil pump

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In items 7-63 through 7-65, select from column B the condition in the combustion chamber that causes each kind of carbon deposit listed in column A.

	A. Carbon Deposits		B. Conditions
7-63.	Soft, dry, black carbon	1.	Worn piston rings
7-64.	Hard, baked-on, black carbon	2.	Lean fuel-air mixture
7-65.	Wet, black carbon	3.	Rich fuel-air mixture
		4.	Cold-type spark plugs

7-66. The best tool to use in adjusting spark plug gap is a

1. round gage
2. flat feeler gage
3. standard gage
4. wire gage

7-67. A tinge of bluish light, called a corona discharge, that appears just above the shell of a spark plug indicates the presence of

1. oil around the plug
2. excessive heat around the plug
3. a low-tension field aroung the plug
4. a high-tension field around the plug

7-68. When spark plugs are replaced, under normal conditions, you should determine the proper heat range by checking the

1. MRC for the unit
2. length of the spark plug
3. the manufacturer's manual
4. the information on the old spark plug

Assignment 8

Reciprocating Gasoline Engines and Diesel Engines

Text: Pages 220 - 254

Learning Objective: Recognize design characteristics of vehicle headlights and taillights, and identify components, maintenance procedures, and safety factors/measures associated with electrical circuits and batteries.

8-1. The permanent bonding of the lens and reflector in sealed beam headlight units makes them superior to older type headlights. Which of the following does NOT support this statement?
1. Entrance of dirt, dust, and moisture between the lens and reflector is prevented
2. Illumination is better and more powerfull
3. Initial brilliance remains nearly constant throughout headlight life
4. Adjustment is easier

8-2. Which of the following statements about stoplights and taillights is INCORRECT?
1. Stoplights and taillights are normally contained in the same housing
2. Stoplights and taillights may be contained in the same bulb
3. Stoplight candlepower is greater than taillight candle power
4. Stoplights and taillights are controlled from the same switch

8-3. A fuse used in the circuit of an individual electrical system will have an ampere rating equal to the
1. minimum current required to operate all units in the system
2. maximum current required to operate all units plus a 10% overload
3. maximum current required to operate all units in the system
4. minimum current required to operate all units plus a 10% overload

8-4. If a current of 60-Hz ac were passed through a human body, what could be the effects of 0.1 ampere for 1 second passing through the body?
1. No effect
2. Fatal
3. Slight illness
4. Light headedness

8-5. Acid burns from electrolyte are hazards associated with
1. batteries
2. hydrogen gas
3. fuses
4. citric acid

8-6. Batteries should be charged outside or in a well ventilated room because of the danger of
1. noxious fumes given off by the electrolyte
2. explosion from the electrolyte
3. explosion from hydrogen gas
4. noxious fumes given off by the hydrogen gas

Learning Objective: Identify when the fuel-air mixture is leanest and how the fuel injector system operates.

8-7. When is the mixture ratio of air to gasoline in the cylinder the leanest?
1. When accelerating
2. During full load operation
3. During the starting of a cold engine
4. Under normal running conditions with a warm engine

8-8. In a fuel-injection fuel system, the injector injects the proper amount of fuel into the
1. cylinder during the intake stroke
2. cylinder during the compression stroke
3. intake manifold during the intake stroke
4. intake manifold during the compression stroke

Learning Objective: Relative to a gasoline engine fuel system, identify tanks, filters, and gages as to types, operating characteristics, and maintenance procedures.

8-9. In the instrument panel unit of the balancing coil type of fuel gage, which components operate the needle when the tank is empty?
1. The operating magnetic coil and the permanent magnet
2. The limiting magnetic coil and the permanent magnet
3. The limiting magnetic coil and the operating magnetic coil
4. The rheostat and the operating magnetic coil

8-10. In the thermostatic-type fuel gage, the pointer in the gage unit is actuated by
1. bimetallic contacts
2. bimetallic blades
3. limiting coils
4. permanent magnets

8-11. What type of fuel filter is most commonly used in Navy vehicles?
1. Ceramic element
2. Paper element
3. Metal disk
4. Metal mesh screen

Learning Objective: Recognize automotive fuel pump types, components, functions, and associated installation practices.

8-12. In addition to delivering fuel to the engine, the fuel pump must also maintain a proper pressure in the line between the
1. pump and the tank
2. pump and the carburetor
3. tank and the carburetor
4. carburetor and the cylinders

8-13. What effect, if any, does excessive fuel-pump pressure have on the fuel consumption of an engine?
1. Fuel consumption is increased
2. Fuel consumption is decreased
3. There is no effect on the amount of fuel consumed
4. Fuel consumption is either increased or decreased depending on whether the pump is positive or nonpositive

8-14. The normal pressure delivered by a fuel pump in operation is
1. 1 to 3 psi
2. 3 to 5 psi
3. 5 to 7 psi
4. 7 to 9 psi

8-15. The carburetor receives fuel from a mechanical fuel pump only when the
1. pressure maintained by the diaphragm spring of the pump is less than the fuel pressure in the outlet
2. pressure maintained by the diaphragm spring of the pump is greater than the fuel pressure in the outlet
3. fuel passage from the pump is opened into the float chamber and the float needle valve is seated
4. fuel passage from the pump is closed and the float needle valve of the carburetor is unseated

8-16. Which type of fuel pump is installed in a housing in the fuel tank?
1. Mechanical single action
2. Mechanical nonpositive
3. Electric autopulse
4. Electric motor driven

8-17. Why are fuel lines placed away from exhaust pipes, mufflers, and manifolds?
1. To reduce the danger of fire if a leak should develop in the line
2. To prevent vaporlocks caused by excessive heat
3. For ease of maintenance
4. To reduce the danger of damage to the fuel lines from excessive heat

8-18. To which of the following are fuel lines on vehicles normally attached for support?
1. Muffler
2. Frame
3. Radiator
4. Tailpipe

Learning Objective: Recognize theories and terms associated with the structure of matter, and identify the purpose of a carburetor's venturi passage.

8-19. Which substances are composed of constantly moving particles called molecules?
1. Solids and liquids
2. Liquids and gases
3. Gases and solids
4. Solids, liquids, and gases

8-20. In which substance are the molecules held closest together?
1. Ice
2. Water
3. Gasoline
4. Gasoline vapor

8-21. The weight of the molecules in the air determines the air's
1. specific gravity
2. atmospheric pressure
3. humidity
4. dew point

8-22. Under which condition does liquid evaporate the fastest?
1. Low temperature and low atmospheric pressure
2. Low temperature and high atmospheric pressure
3. High temperature and low atmospheric pressure
4. High temperature and high atmospheric pressure

In items 8-23 through 8-25, select from column B the chemical term applicable to each fundamental concerning liquids listed in column A.

	A. Fundamentals	B. Terms
8-23.	Molecules of a liquid move from the liquid to the air	1. Carburetion
		2. Atomization
8-24.	The ease with which molecules of a liquid move from the liquid to the air	3. Evaporation
		4. Volatility
8-25.	A liquid is broken into very tiny particles	

8-26. The purpose of the venturi passage in a carburetor is to
1. lower the atmospheric pressure in the float bowl to force the gasoline through the fuel outlet nozzle
2. spray the fuel in the air by increasing the speed of the air entering the carburetor
3. reduce the rate of vaporization by lowering the pressure of the air entering the carburetor
4. create a partial vacuum to permit atmospheric pressure to force the fuel from the float bowl

In items 8-27 through 8-30, select from column B the carburetor system which controls each carburetor action listed in column A.

	A. Carburetor Actions	B. Carburetor Systems
8-27.	Enriches fuel-air mixture for high-speed operation	1. Accelerating system
		2. Maximum power circuit
8-28.	Supplies enriched fuel-air mixture for low-speed, no-load operation	
		3. Float system
8-29.	Momentarily supplies enriched fuel-air mixture when the throttle is initially opened	4. Idling circuit
8-30.	Maintains constant level of fuel in the carburetor bowl	

Learning Objective: Recognize functions and/or operating characteristics of carburetor controls and identify circuits that vary fuel-air ratios.

8-31. Which of the following components regulates the volume of fuel-air mixture which can pass into the intake manifold?
1. Throttle valve
2. Float circuit
3. Venturi
4. Maximum power circuit

● Refer to figure 7-30 in answering items 8-32 through 8-35.

8-32. The idle and low-speed circuit is identified by what letter?
1. A
2. C
3. E
4. G

8-33. Atmospheric pressure which forces fuel down through the idle circuit is admitted to the carburetor at which point?
1. F
2. H
3. I
4. J

8-34. At what place in the carburetor does the gasoline start to atomize?
1. A
2. B
3. C
4. D

8-35. When more fuel is needed to support low-speed operation, the position of the low-speed port will be such that it is just below the edge of
1. A
2. C
3. E
4. G

8-36. In its high-speed circuit, a carburetor maintains a fairly constant ratio of fuel to air, and overrichness is prevented by
1. decreasing the volume of air through the venturi
2. maintaining a constant pressure in the venturi
3. letting more air enter the main nozzle
4. letting less fuel enter the main nozzle

8-37. Which of the following air-to-fuel carburetor ratios by weight will normally produce the most power in the high-speed circuit?
1. 12:1
2. 13:1
3. 14:1
4. 15:1

8-38. To ensure delivery of the proper fuel-air mixture for all operating conditions, each position of the throttle valve must be synchronized with the position of the
1. power jet setting
2. metering rod
3. vacuum step-up mechanism
4. venturi opening

8-39. What component of the accelerating pump circuit meters the amount of fuel used?
1. The lever on the throttle shaft
2. The discharge check valve
3. The intake check valve
4. The accelerating jet

8-40. At steady part-throttle positions, what prevents fuel from flowing back into the carburetor from the accelerator pump cylinder?
1. The throttle valve
2. The air-vent check valve
3. The accelerating jet
4. The metering rod

Learning Objective: Identify functions and operating characteristics of carburetor choke circuits, emphasizing the automatic choke mechanism.

8-41. During starting, a choke alters the fuel-air mixture that enters the manifold of a cold gasoline engine by admitting
1. less air
2. more air
3. less fuel and more air
4. more fuel and less air

8-42. In the automatic choke mechanism, when the engine is cold the choke valve is held closed as a result of
1. high intake manifold vacuum
2. thermostatic spring tension
3. hot air from the exhaust manifold
4. air passing through the carburetor air horn

8-43. An automatic choke closes fully when the temperature of the thermostatic spring decreases to approximately
1. 60° F
2. 70° F
3. 80° F
4. 90° F

Learning Objective: Recognize causes and effects of carburetor malfunctions and the role of an air cleaner in preventive maintenance.

Items 8-44 through 8-50, select from column B the carburetor system malfunction most likely to cause the engine troubles listed in column A.

A. Engine troubles

8-44. Excessive fuel consumption
8-45. Poor idling
8-46. Hard starting of warm engine
8-47. Slow engine warmup
8-48. Smoky, black exhaust emission
8-49. Stalling during warmup
8-50. Backfiring engine

B. Malfunctions

1. Fuel-air mixture too rich
2. Choke defective
3. Fuel-air mixture too lean
4. Throttle linkage adjustment improper

Learning Objective: Relative to automotive air intake and exhaust systems, indicate component functions and structural characteristics, and an associated safety hazard

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8-51. What function does the intake manifold perform?
1. It admits air from the outside to the air filter
2. It routes air from the filter to the carburetor
3. It routes a mixture of air and fuel from the carburetor to the engine
4. It conducts air from the engine to the muffler

8-52. The intake manifold is located so that it can be as short and as straight as possible in order to
1. provide for center feeding from the fuel source
2. provide for advantageous carburetor location
3. reduce heat absorption
4. reduce condensation

8-53. To withstand the intense heat, the gasket between the exhaust manifold and the cylinder block is made of metal covered with
1. asbestos
2. cork
3. leather
4. oil impregnated paper

8-54. What is the purpose of the manifold heat valve?
1. To create a "hot spot" around the exhaust manifold
2. To run the windshield wipers in case the manifold vacuum is insufficient
3. To provide for heating the fuel-air mixture until the engine warms up
4. To provide additional heat inside the vehicle in cold weather

8-55. In addition to quieting exhaust noise by allowing the exhaust gases to expand before leaving the exhaust system, the muffler also functions to
1. aid in heating the vehicle during cold weather operation
2. put pressure on the exhaust side of the valves to increase engine power output
3. prevent flame and sparks from leaving the exhaust system
4. increase the flow of exhaust gases leaving the engine

8-56. Any defective part of the exhaust system, such as the exhaust pipe, tail pipe, or muffler, must be replaced immediately to prevent harm to the equipment operator by the poisonous fumes of
1. carbon monoxide only
2. carbon dioxide only
3. carbon tetrachloride
4. carbon monoxide and carbon dioxide

Learning Objective: Recognize the instrument best suited for evaluating engine performance, and indicate typical causes and effects of engine malfunctions, including identification and maintenance procedures.

8-57. When critical adjustments are made on an engine or tests are made to determine malfunctions, which of the following should be utilized?
1. An engine analyzer
2. A dwell meter
3. A timing light
4. A voltmeter

8-58. A malfunction that prevents a starting system from rotating the engine fast enough to start usually can NOT be traced to
1. a weak battery
2. a poor connection between the battery and starter
3. a defective starter motor
4. improper timing

8-59. A malfunction in which of the following areas requires corrective maintenance by an ASE?
1. Fuel
2. Compression
3. Ignition
4. Timing

8-60. In a repeat test of cylinder compression, an increase in cylinder pressure after heavy oil has been inserted in the cylinder above the piston is a good indication of a faulty
1. set of piston rings
2. exhaust valve
3. intake valve
4. spark plug

8-61. Blue-gray exhaust smoke from an operating engine indicates that the engine is
1. receiving a too-rich fuel-air mixture
2. receiving a too-lean fuel-air mixture
3. burning oil
4. operating normally

8-62. An inspection of a support equipment engine conducted after 210 hours of running time is called a/an
1. preventive maintenance inspection
2. periodic inspection
3. operational inspection
4. preoperational inspection

Learning Objective: Recognize the differences in the construction features and operating principles of gasoline engines and diesel engines, and the advantages and disadvantages of the diesel engine.

8-63. What makes it possible to ignite the fuel-air mixture of a diesel engine without the use of a spark as in a gasoline engine?
1. The ignition temperature of diesel fuel is low
2. The compression ratio of the diesel engine is low
3. The compression temperature of the diesel engine is high
4. The speed of the diesel engine's moving parts is high

8-64. The major differences in the operation of gasoline engines and diesel engines are in their
1. valve and piston systems
2. fuel intake systems and ignition methods
3. air intake systems and fuel mixture methods
4. cooling and exhaust systems

8-65. Which components that are necessary for operation of a gasoline engine are NOT used on a diesel engine?
1. Spark plugs and carburetor
2. Carburetor and intake valve
3. Spark plugs and intake manifold
4. Intake valve and intake manifold

8-66. One advantage of the diesel engine over the gasoline engine is the diesel engine's
1. suitability for vehicles which transport small loads
2. low production costs
3. smoothness of operation
4. high ratio of power output to fuel consumption

Learning Objective: Relative to design and operation, identify types of diesel combustion chambers.

8-67. The advantages of a diesel engine as compared to a gasoline engine include
1. slower acceleration and deceleration and rougher idling at low rpm
2. harder starting and rougher operation at idle and with light loads
3. heavier construction and higher cost to manufacture
4. lower fuel consumption for same power output

8-68. As compared with the other types of combustion chamber design, what does the open-type require with respect to injection pressure and atomization?
1. Higher fuel injection pressure but lower degree of atomization
2. Higher fuel injection pressure and greater degree of atomization
3. Lower fuel injection pressure but higher degree of atomization
4. Lower fuel injection pressure and lower degree of atomization

8-69. What is one difference between the turbulence and precombustion types of chambers?
1. More air enters the turbulence type
2. Faster moving air enters the precombustion type
3. Turbulence is governed by the design of the piston and cylinder head in the precombustion type
4. Combustion takes place completely in the cylinder in the turbulence type

8-70. In the Lanova combustion chamber, combustion takes place first in the
1. turbulence chamber
2. main chamber
3. precombustion chamber
4. energy cell

Learning Objective: Compare components of gasoline engine and diesel engine fuel systems, and recognize operating principles and component functions of diesel fuel supply pumps.

8-71. How do the gears of the gear-type fuel supply pump deliver fuel oil from the suction side of the pump to the discharge side?
1. By moving the fuel oil by suction action
2. By moving the fuel oil trapped between the tooth pockets of the pump gears and the casing
3. By trapping the fuel oil in the pump body
4. By trapping the fuel oil in the driving gear

Learning Objective: Recognize functions of the diesel fuel injection system and how an improperly functioning system affects engine operation.

8-72. Which of the following functions of the fuel injection system ensures that the engine will operate at a uniform speed with a uniform power output?
1. Metering
2. Timing
3. Atomization of fuel
4. Injection rate control

8-73. What is one kind of trouble that can be expected if the timing of a fuel injection system is NOT properly adjusted and the fuel is injected too late in the cycle?
1. Delayed ignition
2. Low exhaust gas temperature
3. Smoky exhaust
4. Excessive wear

8-74. What will be the result if the rate of fuel injection is too high?
1. High exhaust gas temperature
2. Poor fuel economy
3. Delayed ignition
4. Excessive engine speed

8-75. Where does the atomization of fuel occur?
1. Within the turbulence chamber
2. Within the precombustion chamber
3. Between the fuel pump and the injection system
4. Within the injection system

Assignment 9

Diesel Engines and Chassis Systems

Text: Pages 254 - 279

Learning Objective: Relative to diesel fuel injectors, indicate construction features and testing and maintenance practices.

9-1. What is the primary difference between the distribution-pressurized and unit injection types of fuel injectors?
1. The distribution-pressurized type delivers enough pressure to overcome cylinder pressure, whereas the unit injection type does not
2. The unit injector type contains the injection nozzle and pressurization pump in one unit
3. The unit injection type requires a spring-loaded bypass valve on the header to assist in maintaining constant fuel pressure
4. The distribution-pressurized type contains the injection nozzle and pressurization pump in one unit

9-2. In testing the injectors of an engine that fails to operate properly, you cut out one cylinder at a time and observe engine operation. Which of the following conditions indicates a defective injector for the cutout cylinder?
1. The defect is more pronounced
2. The irregular operation of the engine remains unchanged
3. The irregular operation of the engine is eliminated
4. The engine speed increases

9-3. If you do not have special servicing equipment available, it is advisable to do which of the following to a defective injector?
1. Replace it
2. Repair it
3. Clean it
4. Blow it out with air

9-4. What fluid is commonly used to clean injectors?
1. Water
2. Gasoline
3. Wood alcohol
4. Diesel fuel

Learning Objective: Indicate the locations, operating principles, uses, and construction features of diesel fuel filters.

9-5. On an engine with two fuel filters, the secondary filter is usually located between the
1. tank and the supply pump
2. primary filter and the supply pump
3. supply pump and the injector pump or injector
4. primary filter and the tank

9-6. Refer to figure 8-9 in your textbook. How does the metal-disc filter function to remove water from fuel oil?
1. The discs absorb the water particles
2. Dirt trapped between the discs absorbs the water
3. The discs vaporize the water globules
4. The discs are stacked so closely together that the water globules cannot pass between them

9-7. The element of the main fuel filter on an engine is usually made from
1. fine wire mesh
2. lintless, acid-resistant fabric
3. metal wool
4. specially treated paper

Learning Objective: Indicate construction features, operating principles, and functions of the air intake system and its cleaners.

9-8. Although the four strokes of a diesel engine occur in the same order and for the same purpose as the four strokes of a gasoline engine, operation of which stroke is slightly different?
1. Intake
2. Compression
3. Ignition
4. Exhaust

9-9. Air can be forced into the cylinders of a four-stroke engine during the intake stroke by
1. atmospheric pressure only
2. a turbocharger only
3. a supercharger only
4. atmospheric pressure, a turbocharger, or a supercharger

9-10. The turbocharger used on all two-cycle and many four-cycle engines is usually the type that is powered by
1. the camshaft
2. the crankshaft
3. the engine exhaust
4. an electric motor

9-11. Improved combustion results if the air entering the cylinders of an engine during the compression stroke can be given a turbulent motion. What design feature gives the air this turbulence?
1. Vanes in the cylinder intake ports
2. Angled blower output ports
3. Angled cylinder intake ports
4. Turbulators outside the cylinder intake ports

9-12. The dry-type air cleaner used on engines serves the two purposes - removing dust and dirt particles and
1. cooling the air
2. heating the air
3. improving combustion
4. silencing the air intake

9-13. What material is used as the cleaning element of an oil-bath or wet-type air cleaner?
1. Metal wool
2. Cotton fabric
3. Wire screens
4. Paper filter

Learning Objective: Identify diesel engine starting system characteristics and starting procedures.

9-14. To start a diesel engine, enough heat and pressure must be generated to cause the fuel-air mixture in the cylinders to ignite. Whether enough heat and pressure will be generated depends upon the
1. temperature of the fuel prior to injection
2. temperature of the air at the time of mixing
3. cranking speed of the engine
4. fuel-air ratio

9-15. Which of the following statements is correct in comparing diesel engine electric starters and gasoline engine electric starters?
1. The systems are basically the same, but the diesel starter rotates the engine faster
2. The systems are basically the same, but the diesel starter rotates the engine slower
3. The systems are basically the same, and both engines are rotated at the same speed
4. The diesel engine may be rotated either faster or slower depending on whether a 6-volt or 12-volt electrical system is installed on the vehicle

9-16. The accumulator for a hydraulic starting motor can store fluid under sufficient pressure to restart the engine at least
1. one full day
2. one week
3. overnight
4. two full days

9-17. The smaller orifice on the starting valve of a hydraulic starter is opened for the purpose of
1. testing the pressure of the fluid
2. engaging the starter pinion with the flywheel
3. cranking the engine
4. demeshing the starter pinion from the flywheel

9-18. In the primer-type starting aid, the volatile fluid is released into the intake system at the
1. cylinder chamber
2. intake manifold
3. injector nozzle
4. injector pump

Learning Objective: Recognize common diesel engine malfunctions and their causes, and indicate publications used when making preoperational and periodic inspections on diesel engines.

9-19. Hard starting, uneven running, and lack of power may be caused by
1. faulty injection only
2. low cylinder compression only
3. lack of sufficient air only
4. faulty injection, low cylinder compression, and lack of sufficient air

9-20. Low cylinder pressure of an engine can NOT be the result of
1. broken piston rings
2. compression leaking past the valve seats
3. compression leaking past the injectors
4. oil leaking past the piston rings

9-21. The time for and type of inspections to be conducted and the proper inspection procedures to follow in maintaining diesel engines can be found in the
1. Maintenance Requirement Cards (MRCs) for the engine only
2. stampings on the engine
3. manufacturer's instructions only
4. MRCs and the manufacturer's instructions for the engine

Learning Objective: Relative to automotive steering systems, identify components and their functional relationships and recognize installation differences and requirements associated with power steering.

9-22. Refer to figure 9-2. Easy steering and maximum leverage in a steering system are achieved by the tie-rod being
1. a one-piece tie-rod located in front of the axle and connected to the steering gear near the center of the vehicle
2. separated into two approximately equal lengths and connected to the steering gear at the separation point
3. a one-piece tie-rod located in back of the axle and connected to the steering gear through a wishbone-shaped knuckle arm
4. a two-piece tie-rod connected to the steering gear through a wishbone-shaped knuckle arm

9-23. Refer to figures 9-1 and 9-3 in your textbook. The length of the drag link connecting the pitman arm and the steering arm is determined by the distance between the
1. steering arm and the vertical position of the pitman arm
2. steering arm and the steering gear
3. vertical position of the pitman arm and the tie-rod
4. horizontal position of the pitman arm and the steering arm

9-24. The ratio between the number of turns of the steering wheel to the degree of movement of the pitman arm is a function of the
1. worm gear only
2. sector gear only
3. worm gear and sector gear
4. cam

9-25. Low steering gear ratios are used in vehicles possessing which characteristic?
1. Hard to turn
2. Slow moving
3. Fast moving
4. Easy to turn

9-26. What is the basic difference between the steering components of equipment steered by the front wheels?
1. A longer drag link is required
2. The tie-rods are longer
3. The distance from the gear box and pitman arm to the steering knuckle is less
4. A shorter drag link is required

9-27. Which of the following describes a difference between the two kinds of power steering systems?
1. One utilizes a single action power cylinder, whereas the other utilizes a double action power cylinder
2. The manner in which the power cylinder and control valve are installed
3. One employs a high-pressure system, whereas the other employs a low-pressure system
4. The manner in which the power steering pump is connected to the engine

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Learning Objective: Identify techniques involved in front end alignment, including definition and application of associated terms such as pivot inclination, caster, camber, toe-in, and toe-out.

9-28. Kingpin angle is a term referring to the number of degrees that the kingpin is tilted from a vertical position toward the
1. rear part of the vehicle
2. center of the vehicle
3. fore part of the vehicle
4. near side of the vehicle

9-29. Steering knuckle tilt, forward or rearward, is called
1. camber
2. caster
3. pivot inclination
4. toe-in or toe-out

9-30. Caster is a property of front end alignment that tends to which of the following?
1. It maintains the wheels perpendicular to the road, permitting better rolling contact
2. It brings the front wheels back to a straight forward position after a turn
3. It returns the front wheels to a vertical position after a turn
4. It keeps the wheel spindles pointed outward and in line with the axle

9-31. Positive caster is achieved when the knuckle pivots are tilted in which direction?
1. Backward
2. Foreward
3. To the right
4. To the left

9-32. The tilt of the wheels, either in or out at the top, is called
1. pivot inclination
2. toe-in or toe-out
3. camber
4. caster

9-33. Camber is obtained by
1. inserting wedges and shims between the front axle and the spring
2. tilting the wheel spindles slightly downward on the steering knuckles
3. inserting shims between the upper suspension arm and the frame
4. tilting the wheel spindles slightly up on the steering knuckles

9-34. To balance the effects of camber, the wheels should be
1. balanced
2. castered
3. toed-out
4. toed-in

Learning Objective: Identify causes and effects of steering problems, and select methods and devices used in locating and correcting them.

9-35. To check for improperly adjusted or worn linkage connections in the steering system, you should jack up the front end of the vehicle and
1. push out on both front wheels at the same time to check for excessive movement
2. pull in on one front wheel at a time to check for excessive movement
3. grasp the front and rear of each wheel and move the wheel in and out
4. grasp the top and bottom of each wheel and shake to determine the amount of wobble

9-36. When floating turntables are used to check steering errors, the steering mechanism is properly adjusted if, when one wheel is turned 20 degrees, the other wheel turns about
1. 23 degrees
2. 22 degrees
3. 21 degrees
4. 20 degrees

9-37. What piece of equipment is used for measuring wheel alignment, only when a more accurate device is NOT available?
1. Wee-gee board
2. Floating turntable
3. Alignment compass
4. Straight edge

9-38. When a measuring pole is used for checking toe-in, you must properly mark the tires and place the measuring pole between the two marks at the front in order to set the pointer at zero. The distance between the two rear marks should be
1. the same as that between the front marks
2. as specified by the manufacturer
3. greater than that between the front marks
4. less than that between the front marks

9-39. Before you begin to adjust tie-rods, what should you do?
1. Count the number of exposed threads at the ends of the tie-rods
2. Even-up the number of exposed threads at the ends of the tie-rods
3. Tighten the tie-rods
4. Loosen the tie-rods

9-40. In adjusting a tie-rod that is in front of the axle, it is important to keep in mind that a
1. longer tie-rod increases toe-in
2. longer tie-rod decreases toe-in
3. shorter tie-rod decreases toe-in
4. shorter tie-rod increases toe-out

9-41. During repair of the steering system or adjustment of the wheel alignment of a vehicle, it is NOT important to ensure that
1. the vehicle is on a level surface
2. the vehicle remains stationary
3. at least one wheel is blocked on both sides
4. the tires are balanced

Learning Objective: Identify suspension system characteristics, components, and associated maintenance practices, including the functions of springs and shock absorbers.

9-42. Support equipments have suspension systems differing from those of most highway-driven vehicles because
1. comfort of the support equipment operator is not as important
2. other types of suspension systems might interfere with support equipment operation
3. support equipments operate at lower speeds over shorter distances
4. support equipments need a more stable type of suspension system

9-43. Pitching of a vehicle equipped with coil springs can be corrected by
1. reducing the friction in the springs
2. using rubber bumpers to help absorb shock
3. using shock absorbers to dampen the action of the springs
4. removing the spacers between the spring coils

In items 9-44 through 9-46, *select from column B* the component which performs each function listed in column A.

	A. Functions	B. Components
9-44.	Prevents the axle from moving forward or backward	1. Rubber bumper
		2. Torque rod
9-45.	Prevents metal-to-metal contact when the spring is compressed	3. Coil spring
9-46.	Balances spring stiffness and flexibility	4. Shock absorber

9-47. Which of the following functions are performed by double-acting shock absorbers?
1. Checking spring compressions and spring rebound
2. Preventing metal-to-metal contact when the springs are compressed, and checking spring rebound
3. Preventing metal-to-metal contact when the springs are compressed, and absorbing torsion load from the springs
4. Increasing spring flexibility and rebound

9-48. Why are rubber mountings used in fastening shock absorbers to the frame and axle of a vehicle?
1. To prevent overcompression of the springs
2. To prevent noise and wear of parts
3. To provide a controlled rebound of the springs
4. To provide a controlled flexing of the springs

Learning Objective: Relative to vehicle frames, identify alignment procedures, methods of installing and reinforcing frame members, and frame members which are normally replaced rather than repaired.

9-49. Which of the following are installed on a vehicle frame to provide additional strength at the points where frame members are joined together?
1. Frame plates
2. Crossmembers
3. Gusset plates
4. Side members

9-50. When frame gages are used to check a vehicle's forward frame alignment, how many gages must be used, and how must they be sighted?
1. Two gages, sighted from the rear to the front of the vehicle
2. Three gages, sighted from the front to the rear of the vehicle
3. Three gages, sighted from side to side of the vehicle
4. Four gages, sighted from the front to the rear and the rear to the front of the vehicle

9-51. What is the preferred method of installing new members in a vehicle frame when replacement is required?
1. Nuts and bolts
2. Oxyacetylene welding
3. Hot-rivet
4. Arc welding

9-52. Which of the following vehicle frame members, if damaged, is usually replaced rather than repaired?
1. Side rail member
2. Front suspension crossmember
3. Center connecting crossmember
4. Rear suspension crossmember

Learning Objective: Relative to oxacetylene welding and cutting operations, recognize torch functions and characteristics, welding techniques and procedures, acetylene cylinder identification, torch tip and welding rod selection, add safety practices.

9-53. The function of a gas welding torch is to
1. grip the rod and direct it against the metal as the gas mixture is applied to the metal from the hose
2. protect the welder's hand from the intense heat generated by the puddled metal
3. provide a clamping device for the gas tubes and the rods so that they can be held as close together as possible when they join the flame at the point of contact with the metal
4. mix the gases in proper proportions and to direct the flame against the metal

9-54. To distinguish it from technical oxygen, a cylinder of aviator's breathing oxygen is identified by its green color and
1. a white band around the top
2. white triangles on the side
3. a yellow band around the top and bottom
4. black letters on the side

9-55. If oxygen equipment should require lubrication, which of the following should ALWAYS be used?
1. Oil, because it flows easily and can be directed into close areas
2. Grease, because it is thick and reduces spillage
3. Graphite, because it is in powdered form and is easily handled
4. Beeswax, because it is nonflammable

9-56. When equal parts of oxygen and acetylene are mixed, the mixture will burn at an approximate temperature of
1. 4,000° F
2. 4,500° F
3. 6,000° F
4. 10,000° F

9-57. Acetylene gas cylinders are identified by the color yellow and
1. black numbers on each side running lengthwise
2. black letters on each side running lengthwise
3. a black stripe running the length of the bottle on each side
4. two circular black stripes at the base of the bottle

9-58. Acetylene gas should be used only through regulators that reduce its pressure to less than
1. 15 psi
2. 20 psi
3. 25 psi
4. 30 psi

9-59. You can NOT install an oxygen hose on an acetylene regulator because the acetylene fitting
1. is larger
2. is smaller
3. has left-hand threads
4. has right-hand threads

9-60. The low-pressure gage on the oxygen pressure regulator of the portable welding outfit indicates the
1. working pressure of the oxygen
2. amount of oxygen in the cylinder
3. cylinder pressure of the oxygen
4. amount of oxygen being mixed with acetylene

9-61. Which of the following factors will NOT determine the selection of the welding torch tip to be used for a specific job?
1. The experience of the welder
2. The position in which the weld is to be made
3. The material to be welded
4. The length of the job

9-62. The selection of the diameter of a welding rod to be used for a particular weld is based upon the
1. thickness of the metal to be welded
2. kind of metal to be welded
3. size of the torch tip to be used
4. heat range of the metal to be welded

9-63. A neutral flame is best suited for most welding because it
1. is easier to control
2. does not alter the composition of the metal being welded
3. allows the weld to be made with the proper tensile strength and ductility
4. alters the composition of the metal being welded

9-64. Which of the following describes the correct procedure to be used in lighting and adjusting an oxyacetylene torch?
1. Open the torch oxygen valve 1/4 to 1/2 turn; light the torch; adjust the flame by slowly opening the acetylene valve; slowly close the oxygen valve until the neutral flame is formed
2. Open both the torch oxygen and acetylene valves 1/2 turn; light the torch; adjust to neutral flame by slowly closing the oxygen valve
3. Open the torch acetylene valve 1/4 to 1/2 turn; light the torch; adjust the flame by slowly opening the oxygen valve; slowly close the acetylene valve until the neutral flame is formed
4. Open both the torch oxygen and acetylene valves 1/4 to 1/2 turn; light the torch; adjust to neutral flame by slowly closing both valves

9-65. Which of the following is the prescribed manner in which to hold an oxyacetylene torch in order to make a proper weld?
1. The white cone of flame should be held vertically in line with the weld joint and approximately 1/2 inch from the surface of the weld
2. The white cone of flame should be held approximately 1/8 inch from the surface of the weld at an angle of 30 to 60 degrees from the perpendicular
3. The white cone of flame should be held approximately 3/4 inch from the surface of the weld at an angle of 30 to 60 degrees from the perpendicular
4. The tip of the torch should be held vertically in line with the weld joint and the distance of the white cone of flame from the surface of the weld is determined by the thickness of the metal to be welded

9-66. An oxyacetylene cutting torch tip differs from a conventional welding torch tip in that
1. it permits the passage of a larger volume of oxygen and acetylene gas, thus creating more heat
2. the heating flame is fed from a central outlet surrounded by several high-pressure oxygen outlets
3. the heating flame is fed from several holes in the tip arranged in a ring around a central high-pressure oxygen outlet
4. the heating flame is fed from one large hole in the tip for an increase in outlet of oxygen

Assignment 10

Power Trains

Text: Pages 281 - 307

Learning Objective: Relative to power train clutches, recognize their purposes, types, construction features and method of power transmission including functions and adjustments of related components.

10-1. Which statement describes one of the main functions of the clutch in the power train of a motor vehicle?
1. It dampens vibration in the transmission system
2. It allows the brakes to "clutch" or hold while the vehicle is in motion
3. It transmits braking power from the wheels to the engine
4. It allows the engine to take up the vehicle-drive load gradually

10-2. In most motor vehicles, the clutch is located between the
1. transmission assembly and differential carrier
2. engine and transmission assembly
3. differential carrier and axle housing
4. release yoke and flywheel housing

10-3. The plate clutch of a motor vehicle transmits power from the driving member to the driven member by employing
1. friction between the driving member and the driven member
2. spring torsion on the plates
3. hydraulic torsion on the plates
4. slippage between the driving member and the driven member

10-4. In most installations the clutch pedal and the clutch release yoke are connected in what manner?
1. Mechanically
2. Hydraulically
3. Electrically
4. Pneumatically

10-5. The clutch of a motor vehicle may be damaged by slippage or by the driver riding the clutch. In what part of the clutch would you expect to find the damage caused by either action?
1. Clutch release yoke
2. Driven member disc
3. Clutch facings
4. Clutch linkage

10-6. When new linings are installed on the driven member of a clutch, which of the following statements is CORRECT in reference to riveting the linings to the disc?
1. The front lining is riveted first
2. The rear lining is riveted first
3. The front and rear linings are riveted simultaneously
4. It makes no difference which lining is riveted first

10-7. Which of the following types of clutches is most often used in light automotive ground support equipment?
1. Plate
2. Multiple disc
3. Hydraulic
4. Cone

10-8. A clutch pedal with too much free movement will NOT cause damage to which of the following?
1. Pressure plate
2. Clutch facings
3. Throw-out bearing
4. Transmission

Learning Objective: Identify clutch malfunctions and determine probable cause and effect of slipping, chattering or grabbing, dragging, unusual noise, pedal pulsations, and rapid disc facing wear.

10-9. Heat generated by slipping clutches may cause small cracks on the
1. pressure plate and clutch facings only
2. pressure plate and flywheel only
3. pressure plate, flywheel, and clutch facings
4. clutch facings only

10-10. Prior to conducting the test for clutch slippage, the vehicle engine must be started and the handbrake set. Then, to conduct the test, the clutch should be released in what manner?
1. Rapidly while accelerating the engine
2. Rapidly while maintaining engine speed constant
3. Slowly while accelerating the engine
4. Slowly while maintaining engine speed constant

10-11. Excessive or insufficient clutch pedal lash requires that you first check the
1. linkage adjustment
2. friction disc facings for surface condition
3. release lever adjustment
4. release bearing for wear or dryness

10-12. Which of the following conditions within the clutch will cause slippage?
1. Too much pedal lash
2. Loose spring shackles
3. Weak or broken pressure springs
4. Broken clutch plate

10-13. Which of the following conditions may be the cause of chattering or grabbing by the clutch when it is engaged?
1. Cracked or checked disc facings
2. Loose disc facings
3. Weak pressure springs
4. Too much free play

10-14. When a disengaged clutch drags, attention should first be given to the
1. pressure plate linings
2. pressure release bearing
3. disc facings
4. pedal-linkage adjustment

In items 10-15 through 10-18, select from column B the condition that may be caused by each defective clutch component listed in column A.

	A. Components	B. Conditions
10-15.	Warped pressure plate	1. Clutch drags when disengaged
10-16.	Glazed disc facings	
10-17.	Broken cushion springs in the disc	2. Clutch chatters when engaging
10-18.	Worn disc facings	
		3. Clutch slips

10-19. If excessive wear is found on the clutch shaft, you should check for
1. engine and transmission alignment
2. weak disc dampener springs
3. a worn release bearing
4. a dry pilot bearing

10-20. If a disengaged clutch makes a noise, the probable cause is a defective
1. disc hub
2. disc damper spring
3. clutch shaft
4. clutch release bearing

10-21. If slight pressure is applied to the clutch pedal and noticeable pulsations are felt, which of the following conditions may NOT exist?
1. Improper alignment of the engine and transmission
2. A bent crankshaft flange
3. An improperly seated flywheel
4. Free pedal play

10-22. Which of the following conditions will cause rapid clutch disc wear?
1. Slippage
2. Chatter
3. Drag
4. Pilot bearing wear

Learning Objective: Recognize purposes, types, and functions of transmissions and indicate power flow for various gear positions including the effects of various gear ratios.

10-23. How does an automotive transmission function to meet the various speed and power requirements of the engine?
1. By slowing down
2. By the shifting of gears
3. By speeding up
4. By a transfer of power

10-24. The purpose of the motor vehicle's transmission is to transfer power from the clutch shaft directly to the
1. rear wheels
2. idler shaft
3. propeller shaft
4. differential

● Refer to figure 10-7 in your textbook in answering items 10-25 through 10-29.

10-25. In A, maximum power is produced because the smallest countershaft gear meshes with the
1. smallest sliding gear
2. largest sliding gear
3. second largest sliding gear
4. constant speed gear

10-26. In gear arrangement C, the forward slide gear has meshed with the
1. smallest countershaft gear
2. largest countershaft gear
3. second countershaft gear
4. constant speed gear

10-27. In gear arrangement D, the forward sliding gear is meshed with the
1. smallest countershaft gear
2. largest countershaft gear
3. second countershaft gear
4. constant speed gear

10-28. Gear arrangement D allows the engine crankshaft and the propeller shaft to revolve at a ratio of
1. 1:1
2. 2:1
3. 3:1
4. 4:1

10-29. In gear arrangement E, the idling gear is moved by the second shifting fork until it meshes with the
1. large countershaft
2. small sliding gear
3. large sliding gear
4. small countershaft

10-30. If the engine speed remains constant, which of the following gear combinations will give the most speed to the vehicle?
1. A driving gear with 50 teeth and a driven gear with 10 teeth
2. A driving gear with 100 teeth and a driven gear with 50 teeth
3. A driving gear with 25 teeth and a driven gear with 25 teeth
4. A driving gear with 20 teeth and a driven gear with 6 teeth

10-31. What is the approximate gear ratio of most passenger car transmissions in both low and reverse gear combinations?
1. 12:1
2. 2:1
3. 3:1
4. 4:1

Learning Objective: Recognize operating and design characteristics of transmissions.

10-32. The constant mesh transmission reduces noise by utilizing
1. spur-tooth gears rather than helical gears
2. helical gears rather than spur-tooth gears
3. mainshaft meshing gears that can move endwise
4. soundproof padding around the transmission unit

10-33. In actual practice, the constant mesh gear is seldom used in which gears?
1. First and second
2. First and reverse
3. Second and third
4. Third and fourth

10-34. The driving and driven members of a synchromesh transmission are brought to the same speed by the engagement of the
1. dog clutch only
2. dog clutch and the friction cone clutch at the same time
3. friction cone clutch only
4. clutch plate facing and the dog clutch at the same time

10-35. The synchromesh transmission shown in figure 10-11 engages the notches at the inner ends of the bellcranks by means of
1. shifter forks
2. poppets
3. a dog clutch
4. a first speed clutch

Learning Objective: Relative to automotive transmission trouble, identify troubleshooting techniques including associated malfunctions, and select transmission repair, assembly, and testing procedures.

10-36. Before concluding that a noise originates in the transmission, which of the following should the troubleshooter NOT eliminate as possible sources?
1. Worn universal joints
2. Unbalanced tires
3. Defective wheel bearings
4. Rear end drive

10-37. Which of the following may cause torsional vibration but NOT result in a noise which appears to originate in the transmission?
1. Drive shaft out of balance
2. Wheels out of balance
3. Worn universal joints
4. Front end alignment

10-38. Before you remove the transmission assembly from a vehicle, what should you ensure is done?
1. The transmission is filled with lubricant
2. The lubricant is drained from the transmission
3. The transmission is filled with flushing oil
4. Obvious oil leaks are marked on the assembly case

10-39. The transmission of a motor vehicle is removed and inspected. Which of the following may indicate the presence of small holes or cracks in the transmission case?
1. Tightness of the gears
2. Oil dampness around the gaskets and oil seals
3. Moist oil spots on the transmission case
4. Low level of transmission grease

10-40. If small cracks in the transmission case of a vehicle extend into the bearing bores, the bores may be repaired by the application of
1. special cast iron welding techniques
2. ordinary welding techniques
3. ordinary brazing techniques
4. ordinary soldering techniques

10-41. How should you prepare leather oil seals before you install them in a transmission?
1. Coat them with light oil
2. Coat them with medium oil
3. Soak them in light oil for 45 minutes
4. Soak them in medium oil for 45 minutes

10-42. Transmission parts that are ready for assembly should be coated with
1. light lubricating oil
2. rust preventive compound
3. medium grade preservative lubricating oil
4. fiber grease

10-43. After a transmission is assembled, you should test it by
1. installing it in a vehicle and driving the vehicle
2. mounting it on a test stand, connecting the stand to an auxiliary engine, and running the engine
3. rotating its input shaft at least 10 times with a suitable wench
4. rotating its input shaft at least one complete revolution

Learning Objective: Recognize the function of a transfer case in an automotive power train, the reasons why an ASM must have a knowledge of the basic principles of an automatic transmission, and identify the fundamentals of hydraulics as they apply to automatic transmissions.

10-44. When a four-wheel drive automotive vehicle requires additional traction, what transfer device automatically provides front wheel drive?
1. The power takeoff
2. The sprag unit
3. The auxiliary transmission
4. The two-way clutch

10-45. The speed with which liquid flows from one place to another through a confined space is determined by the liquid's

1. viscosity
2. specific gravity
3. density
4. compressibility

10-46. Which of the following statements is correct concerning pressure applied to liquid that completely fills a container?

1. Equal amounts of pressure are transmitted to the liquid and the walls of the container, but at right angles to the direction from which the pressure is applied
2. Pressure is transmitted equally and without loss to all portions of the liquid and the walls of the container
3. Half the pressure is transmitted to the walls of the container in the direction of application, and the other half compresses the liquid
4. Half the pressure is transmitted to the liquid and the walls of the container in the direction of application, and the other half at right angles to that direction

● Refer to figure 10-17 in your textbook in answering items 10-48 and 10-49.

10-47. If force 1 is 25 pounds, force 2 will be

1. 12.5 lb
2. 25.0 lb
3. 125.0 lb
4. 250.0 lb

10-48. If a piston 1 moves a distance of 2 inches, what distance will piston 2 be moved?

1. 0.2 in.
2. 1.6 in.
3. 2.4 in.
4. 3.0 in.

Learning Objective: Identify constuction features and principles of operation of automatic transmission fluid couplings and torque converters, and describe the manner in which they function under various transmission load conditions.

10-49. The rear torus of the fluid coupling is attached directly to the

1. flywheel
2. crankshaft
3. transmission input shaft
4. clutch housing

10-50. In the fluid coupling, centrifugal force of the oil transfers kinetic energy to the

1. front torus
2. turbine blades
3. clutch plate
4. pump

10-51. As the speed difference between the pump and the turbine in a fluid coupling approaches the low vortex stage, what is the action of the vortex coils?

1. They become closer together
2. They become further apart
3. They become stationary
4. They rotate faster

10-52. When does zero vortex occur in the fluid coupling?

1. When the pump and turbine are completely stopped
2. When the pump and turbine are rotating at the same speed
3. When the pump is rotating much faster than the turbine
4. When the pump is rotating much slower than the turbine

10-53. Which of the following is NOT an advantage of a fluid coupling?

1. Sudden jerks by the engine are not transmitted to the gears
2. Engine vibrations are not transmitted to the rest of the power train
3. It prevents engine overload
4. There is no slippage between the engine and drive

10-54. In a torque converter, the vortex of oil is redirected as it returns to the drive member by the

1. pump
2. stators
3. fluid coupling
4. transmission

10-55. The secondary pump of a torque converter begins to assist the pump when the

1. pump begins operating
2. turbine begins operating
3. pump and turbine are operating at about the same speed
4. pump is turning faster than the turbine

10-56. A torque converter functions like a fluid coupling when the
1. secondary pump stops overrunning
2. secondary pump is overrunning
3. secondary stators are in operation
4. primary stators are in operation

10-57. In every case, the function of the added members of a five-member torque converter is to
1. reverse the direction of the oil leaving the turbine when the turbine and pump are operating at any speed
2. reverse the direction of the oil leaving the turbine when considerable difference exists between turbine and pump speeds
3. lock out the torque converter thereby preventing slippage between the driving and driven shafts
4. enable the torque converter to act as a conventional clutch

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Learning Objective: Identify characteristics and functions of planetary gear systems and related components, and recognize conditions of power transmission through a planetary system including the solving of related gear ratio problems.

In items 10-58 through 10-60, select from column B an operational characteristic of each planetary gear component listed in column A.

	A. Components	B. Characteristics
10-58.	Planet pinion	1. Has internal teeth
10-59.	Ring gear	2. Occupies the central position in the unit
10-60.	Sun gear	
		3. Rotates around the central components of the unit
		4. Has two smooth surfaces around which gears revolve

10-61. Which of the following is considered to be an advantage of the planetary gear system of a vehicular transmission?
1. There is little gear tooth contact and therefore little friction in the system
2. There is little tooth damage to the gears because they are seldom meshed
3. There is no need for special skill on the part of the driver for operation of the gear system
4. There is rarely any contact between more than two gears in the system

Items 10-62 through 10-66 relate to figure 10-24 in your textbook.

10-62. The condition under which the gears are operating is a case of
1. reverse reduction
2. minimum overdrive
3. minimum reduction
4. maximum reduction

10-63. The propeller shaft is connected to the
1. planet gears
2. planet carrier
3. sun gear
4. ring gear

10-64. In relation to the direction and speed of crankshaft rotation, the propeller shaft rotates in the
1. same direction and at the same speed
2. opposite direction and at the same speed
3. same direction but at a different speed
4. opposite direction but at a different speed

10-65. To determine the speed ratio between the crankshaft and the propeller shaft, you must know the number of teeth in
1. the sun gear and the ring gear
2. the sun gear and all of the planetary gears
3. all of the planetary gears and the ring gear
4. all of the gears in the assembly

10-66. In minimum reduction, the engine drives the
1. sun gear
2. ring gear
3. planetary gears
4. planetary carrier

10-67. The speed reduction in the case shown in figure 10-25 of your textbook may be calculated by which of the following procedures?

1. Add the number of teeth in the sun gear to the number of teeth in the ring gear, and divide the sum by the number of teeth in the sun gear
2. Add the number of teeth in the sun gear to the number of teeth in the planet gears, and divide the sum into the number of teeth in the planet gears
3. Add the number of teeth in the sun gear to the number of teeth in the ring gear, and divide the sum into the number of teeth in the planet gears
4. Add the number of teeth in the sun gear to the number of teeth in the ring gear, and divide the sum into the number of teeth in the ring gear

Assignment 11

Power Trains and Hardware; Fuels, Lubricants and Hydraulic Fluids

Text: Pages 307 - 339

Learning Objective: Identify construction features and principles of operation of automatic transmissions, fluid couplings, torque converters, and describe the manner in which they function under various transmission load conditions (continued).

11-1. In reverse reduction, the propeller shaft is connected to which of the following components?
1. Sun gear
2. Ring gear
3. Planet gears
4. Planet carrier

11-2. Refer to figure 10-26. If the ring gear has 48 teeth and the sun gear has 24 teeth, the speed reduction is
1. one-fourth
2. one-half
3. three-fourths
4. zero

11-3. Minimum overdrive is accomplished by the engine driving the
1. planet carrier and the sun gear driving the propeller shaft
2. planet gears and the ring gear driving the propeller shaft
3. planet carrier and the ring gear driving the propeller shaft
4. sun gear and the ring gear driving the propeller shaft

11-4. A speed increase in minimum overdrive may be calculated by adding the number of teeth in the
1. sun gear to the number of teeth in the ring gear, then dividing the sum by the number of teeth in the sun gear
2. sun gear to the number of teeth in the ring gear, then dividing the sum by the number of teeth in the ring gear
3. sun gear to the number of teeth in the plant gears, then dividing the sum by the number of teeth in the sun gear
4. planet gears to the number of teeth in the ring gear, then dividing the sum by the number of teeth in the ring gear

11-5. When the engine drives the planet carrier and the sun gear drives the propeller shaft with the ring gear held against rotation, the system is operating in
1. reverse reduction
2. reverse overdrive
3. maximum overdrive
4. minimum reduction

11-6. Refer to figure 10-28 of your textbook. If the sun gear has 12 teeth and the ring gear has 48 teeth, the ratio between engine rotation and propeller shaft rotation will be
1. 1:1
2. 1:2
3. 1:3
4. 1:5

11-7. If any member of a planetary gear system is held locked to any one of the other members, the system will operate in
1. direct drive
2. minimum overdrive
3. maximum overdrive
4. reverse overdrive

11-8. The only condition under which a planetary gear system may be operated to obtain a 1:1 ratio between engine speed and propeller shaft speed is in
1. maximum overdrive
2. minimum overdrive
3. direct drive
4. neutral

11-9. If the sun gear is driven by the engine and none of the other components are locked together or held against rotation, the system will operate in
1. maximum overdrive
2. minimum overdrive
3. direct drive
4. neutral

● In answering items 11-10 through 11-12, refer to table 10-2 in your textbook and to the following information:

● The planetary unit of an automatic transmission has a ring gear containing 40 teeth, a sun gear containing 20 teeth, and is turned by a crankshaft at 900 rpm.

11-10. If the engine is connected to the sun gear and the propeller shaft is connected to the planet carrier, what is the speed of the propeller shaft?
1. 300 rpm
2. 600 rpm
3. 900 rpm
4. 2,700 rpm

11-11. How must the engine and propeller shaft be connected to this planetary unit in order to obtain a propeller shaft rotation speed of 600 rpm?
1. Engine to ring gear, propeller shaft to planet carrier
2. Engine to sun gear, propeller shaft to planet carrier
3. Engine to planet carrier, propeller shaft to sun gear
4. Engine to planet carrier, propeller shaft to ring gear

11-12. In reverse reduction, in what direction and at what speed will the propeller shaft rotate?
1. Same direction as the crankshaft at 450 rpm
2. Opposite to that of the crankshaft at 450 rpm
3. Same direction as the crankshaft at 600 rpm
4. Opposite to that of the crankshaft at 600 rpm

11-13. Automatic transmission gear ratio selection may be affected by
1. vehicle speed only
2. terrain conditions only
3. the driver's demands only
4. vehicle speed, terrain conditions, or driver's demands

11-14. Maintaining the balanced pressure plan in automatic transmissions is the function of various control valves which can be operated by the action of
1. throttle valve pressure only
2. engine vacuum only
3. return spring pressure only
4. throttle valve pressure, engine vacuum, or return spring pressure

Learning Objective: Identify shaft drive assemblies and components as to types, purposes, and maintenance procedures.

11-15. A slip-joint in a propeller shaft assembly in the power train of a vehicle is necessary because
1. the distance between the engine and the transmission varies
2. the distance between the transmission and the differential varies
3. the differential moves up and down
4. a torsion shock absorber is necessary in the power train

11-16. The purpose of the differential in the rear axle assembly is to
1. connect the rear axles together to act as a single axle
2. permit both drive axles to be driven as a single unit even when they are driven at different speeds
3. prevent the rear axles from turning at different speeds
4. boost engine power transmitted to the wheels

11-17. In a left turn the no-spin differential applies full drive to the
1. left rear wheel
2. right rear wheel
3. left front wheel
4. right front wheel

11-18. If a vehicle produces a humming noise in the differential when being driven straight on a smooth surface, this usually means that the
1. drive ring gear or drive pinion gear needs adjusting
2. drive ring gear or differential side gears are too tight
3. differential pinion gears or differential side gears are too tight
4. differential must be replaced

11-19. What type of rear axle is used in most ground support equipment?
1. Plain
2. Semifloating
3. Full floating
4. Three-quarters floating

11-20. Which of the following procedures should be followed when one end of a vehicle is raised from the ground to allow service or work to be performed on the drive train assemblies?
1. The jack or lifting device used to raise the vehicle should be blocked and supplemented with two safety stands
2. A minimum of two jacks should be used to support the vehicle
3. A jack with a 5-ton lifting capacity should be used and supplemented with two safety stands
4. A minimum of two safety stands should be used to support the vehicle in place of the lifting device that raised it

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Learning Objective: With respect to hardware and consumable materials, indicate procedures of selecting hardware and materials.

11-21. What is the purpose of seals used throughout the systems of ground support equipment?
1. To increase friction
2. To minimize leakage
3. To facilitate alignment
4. To facilitate connections

11-22. Hardware used on sliding or moving assemblies in the shape of O-rings or other shapes are called
1. washers
2. gaskets
3. packings
4. bushings

11-23. Hardware used on nonmoving fittings and bosses are called
1. washers
2. gaskets
3. packings
4. bushings

11-24. Backup rings are NOT required in hydraulic systems with less than what maximum pressure?
1. 1,000 psi
2. 1,500 psi
3. 3,000 psi
4. 3,500 psi

11-25. How are O-rings identified?
1. By the stamp on the O-ring
2. By color coding
3. By technical information printed on the O-ring
4. By technical information printed on the O-ring package

11-26. An O-ring manufactured in the third quarter of 1975 would have a cure date on the package of
1. 1Q75
2. 2Q75
3. 3Q75
4. 4Q75

11-27. When should the preservation of the O-ring be removed?
1. When ready for installation
2. After installation
3. Three hours prior to installation
4. Twelve hours prior to installation

11-28. Gaskets should NOT be compressed against
1. end caps
2. smooth faces
3. torqued smoothed faces
4. irregular or rough surfaces

11-29. The purpose of the cylinder head gasket is to maintain a
1. gas and coolant-tight seal
2. gas and lubricant-tight seal
3. lubricant and coolant-tight seal
4. lubricant and air-tight seal

11-30. What are the three principle parts of the bolt?
1. Head, thread, extender
2. Head, thread, shaft
3. Head, thread, grip
4. Head, thread, length

Learning Objective: Recognize components, properties, characteristics, and stages of combustion of gasoline, and indicate causes, results, and remedies for detonation.

11-31. Excessive choking of an engine in cold weather should be avoided because it leaves excessive amounts of unvaporized fuel in the intake and combustion system which, in turn

1. prevents proper fuel-air mixture from entering the system
2. seeps into the crankcase and dilutes the lubricating oil
3. causes the engine to overspeed when it warms up
4. reduces the operational economy of the engine

In items 11-32 through 11-35, select from column B the stage of combustion in which each event listed in column A occurs.

	A. Events	B. Stages
11-32.	Effective burning occurs	1. Formation of a nucleus
11-33.	A small ball of blue flame develops in the gap of the spark plug electrodes	2. Hatching out 3. Propagation 4. Dissipation of energy
11-34.	Fingers of flame are sent into the mixture in the combustion chamber	
11-35.	If it should take place, detonation occurs	

11-36. Detonation can result in destruction of an engine. However, the most likely result of detonation will be

1. high fuel consumption only
2. power loss only
3. overheating only
4. power loss, overheating, and high fuel consumption

11-37. The best way to minimize knocking or detonation is to

1. use hot spark plugs
2. put heavy oil in the crankcase to increase ring sealing capabilities thereby increasing compression in the cylinders
3. use a gasoline of the octane recommended for the engine
4. preheat the fuel prior to injection into the cylinders

11-38. How should the spark be adjusted with respect to the octane rating of a fuel?

1. Advance the spark when higher octane fuel is used
2. Retard the spark when higher octane fuel is used
3. Advance the spark when lower octane fuel is used
4. Either retard or advance the spark when higher octane fuel is used, depending on the heat rating of the spark plugs

11-39. Tetraethyllead is added to gasoline for the purpose of

1. decreasing the volatility of the gasoline
2. improving the starting qualities of the gasoline
3. reducing the rate at which gasoline burns
4. increasing the octane rating of the gasoline

11-40. Since the Navy uses fuels of specified octane ratings, detonation in a support vehicle engine may be caused by

1. preignition only
2. a lean fuel mixture only
3. a defective cooling system only
4. a defective cooling system, a lean fuel mixture,or preignition

11-41. Which elements contained in gasoline make it burn freely in air?

1. Oxygen and hydrogen
2. Carbon and hydrogen
3. Carbon and oxygen
4. Carbon and nitrogen

11-42. Which property of gasoline determines its tendency to change from a liquid to a vapor at varying temperatures?

1. Purity
2. Antiknock quality
3. Volatility
4. Uniformity

11-43. The best way to prevent vapor lock during hot weather is to
1. insulate all parts of the fuel system from the hot engine parts
2. remove the engine thermostat so that the engine will run cooler
3. use a fuel of high volatility
4. use a fuel of low volatility

Learning Objective: Recognize requirements and characteristics of diesel fuels and engines.

11-44. Which quality of diesel fuel is considered the most important and necessary?
1. Volatility
2. Viscosity
3. Cleanliness
4. Ignition quality

11-45. Why is water more objectionable in diesel fuel than in gasoline?
1. Diesel fuel must ignite without a spark and water reduces this capability
2. Diesel fuel is lighter than gasoline and mixes readily with water, and the filter system cannot prevent water from passing through the fuel system
3. Water causes rough running and will also corrode the injectors very quickly
4. The cooling effect of water retards diesel ignition

11-46. Which of the following statements concerning the viscosity of diesel fuel is correct?
1. The higher its viscosity, the less will be its resistance to flow
2. The higher its viscosity, the greater will be its resistance to flow
3. The lower its viscosity, the greater will be its resistance to flow
4. The viscosity of the fuel has no effect on its resistance to flow

11-47. Why do diesel engines knock when first started or when idling?
1. Diesel engines have a very high compression ratio and the fuel ignites too early
2. Diesel fuel does not burn fast enough at a low temperature or with low compression
3. There is a delay between the time of injection and ignition
4. Diesel engines have low compression and the fuel ignities too late

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Learning Objective: Recognize requirements and characteristics of JP-5 fuel.

11-48. JP-5 while burning for two hours in a piston engine will produce approximately how many horsepower?
1. One horsepower
2. Five horsepower
3. Three horsepower
4. One-half horsepower

11-49. JP-5 with a vapor pressure of approximately 0 psi is what type of fuel?
1. Gasoline
2. Kerosene
3. Diesel
4. AvGas

11-50. What type of additive is found in gasoline that is NOT found in JP-5?
1. Toluene
2. Xylene
3. Tetraethyllead
4. Cumenelead

Learning Objective: Indicate functions, characteristics, purposes of additives, and uses of lubricating oils and greases.

11-51. Although the primary function of lubricating oil in an internal combustion engine is to prevent metal-to-metal contact of moving parts, it must also function as a
1. coolant only
2. cleanser only
3. sealing agent only
4. coolant, cleanser, and sealing agent

11-52. Which characteristic of lubricating oil is most important when you are determing the oil to use in a diesel engine equipped with an oil cooler?
1. Viscosity
2. Cleaning capability
3. Sealing quality
4. Oxygen absorption capability

11-53. Detergents are added to lubricating oils to aid in cleaning dirt, gum, and other impurities from the engine and then neutralizing them by
1. forming heavy globules with the impurities which then settle to the bottom of the pan
2. holding the impurities in suspension in the oil
3. forming large globules with the impuritites which are then trapped in the filtering system
4. vaporizing the impurities so they can be vented from the crankcase

11-54. Why should lubricating oil be changed at regular intervals?
1. Because of its change in viscosity
2. Because of its increase in acid content
3. Because of its buildup of gum and varnish
4. Because dirt, gum, and other impurities are held in suspension in it

11-55. Under the system established by the Society of Automotive Engineers (SAE) for classifying lubricating oils, oil is characterized by its
1. specific gravity
2. flash and fire points
3. viscosity
4. detergent capability

11-56. In addition to its being used in the engine, lubricating oil is also used in the
1. gear unit transmission only
2. differential only
3. steering gear unit only
4. transmission, differential, and steering gear unit

11-57. Which of the following statements describes the viscosity characteristics of an oil with a low viscosity index?
1. It becomes thin at low temperatures and thick at high temperatures
2. It becomes thick at low temperatures and thin at high temperatures
3. It remains thin at all temperatures
4. It remains thick at all temperatures

11-58. What is the MILSPEC of the type of lube oil that is used in a gas turbine engine?
1. MIL-L-7808
2. MIL-L-9502
3. MIL-L-23699B
4. MIL-L-1010

11-59. In addition to satisfactory performance in operation, the most important requirements for grease include
1. stability only
2. noncorrosiveness only
3. water resistance only
4. stability, noncorrosiveness, and water resistance

11-60. In the manufacture of grease, soaps are added to regulate water resistance and
1. heat stability
2. corrosive action
3. oxidation
4. consistency

Learning Objective: Indicate properties and types of hydraulic fluid, the results of mixing different types, and your role in hydraulic system maintenance.

11-61. What property of hydraulic fluid indicates its desirable characteristics of resistance to combustion and evaporation?
1. A low viscosity index
2. A high flashpoint
3. Chemical stability
4. Freedom from acidity

11-62. The hydraulic fluid most commonly used in aviation support equipment has what type of base?
1. Petroleum
2. Vegetable
3. Synthetic
4. Mineral

11-63. As an ASM, your maintenance on a hydraulic system will normally be limited to
1. measuring system pressure
2. checking and adding fluid
3. routine tightening of connections
4. replacing filters

Learning Objective: Recognize hazards and safety precautions associated with petroleum products.

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11-64. Although the handling of all petroleum products can create hazards, what is the most hazardous to handle because of its toxic and highly combustible vapors?
1. Lubricating oil
2. Hydraulic fluid
3. Diesel fuel
4. Gasoline

11-65. Compared to the weight of air, vapors from petroleum products are
1. lighter
2. heavier
3. the same weight
4. either lighter or heavier, depending on which product is producing the vapors

11-66. What is the maximum time that a person may be exposed to petroleum vapors without serious effects?
1. 6 min
2. 10 min
3. 15 min
4. 20 min

11-67. What type of fire extinguisher is recommended for use on petroleum fires?
1. Dry chemical only
2. Water-acid
3. CO_2 only
4. Dry chemical or CO_2

Assignment 12

Gas Turbine Compressors and Air Conditioners

Text: Pages 341 - 371

Learning Objective: Relative to gas turbine compressor units (GTC), recognize capabilities, similarities, and differences as related to purpose, general operating characteristics, functions of major components, and associated hazards.

12-1. The prolonged life of the gas turbine engine depends upon
1. knowledge of the pilot
2. proper weight of oil
3. knowledge of maintenance personnel
4. use of no-lead gasoline

12-2. What are the two basic types of gas turbine engines?
1. Centrifugal-flow and axial-flow
2. Centrifugal-flow and radial-flow
3. Centrifugal-flow and in-line
4. Centrifugal-flow only

12-3. Which gas turbine engine is most commonly used in ground support equipment?
1. Reverse-flow
2. Centrifugal-flow
3. Axial-flow
4. Turbo-jet

12-4. The gas turbine engine has how many major sections?
1. One
2. Two
3. Three
4. Four

12-5. The gas turbine compressor mounted on the MD-3 is mainly used at
1. shore stations only
2. aboard ship only
3. shore stations and aboard ship
4. depot-type maintenance activities

12-6. The NCPP-105 compressor supplies how many pressure ratios of compressed air?
1. Five
2. Two
3. Three
4. Four

12-7. In reference to the air reaching the compressor unit, which of the following statements is correct?
1. The air must be available in the same quantity required to operate reciprocating engines
2. The air must reach the compressor free from turbulence
3. The air must be heated to a high temperature
4. The air must be under extremely high pressure

12-8. Limitation of the amount of fuel burned in the combustion chamber is based upon the
1. maximum pressure that can be tolerated by the turbine
2. maximum amount of kinetic energy needed to perform the operations of the turbine
3. minimum temperature needed to operate the turbine
4. maximum temperature that can be tolerated by the turbine

12-9. Uniformly mixed air and fuel in an air to fuel ratio of less than 50 to 1 will not burn. This difficulty is overcome in the combustion chamber by
1. admitting only a small portion of the incoming air until ignition occurs
2. igniting the fuel first and then admitting the air
3. heating the fuel first so that it expands and ignites more easily
4. heating the air first so that ignition occurs more rapidly

12-10. The kinetic energy of the burned gases from the combustion chamber is converted to shaft power by which of the following sections of the unit?
1. Compressor only
2. Turbine only
3. Accessory only
4. Turbine, compressor, and accessory

12-11. Air used in operating pneumatic equipment is taken from what part of the unit?
1. Turbine section
2. Combustion chamber
3. Compressor section
4. Accessory section

In items 12-12 through 12-14, select from column B the section of the unit that performs each function listed in column A.

	A. Functions	B. Sections
12-12.	Provides direct drive to the oil pump assembly	1. Compressor
		2. Combustion chamber
12-13.	Provides drive for the entire unit	3. Power turbine
		4. Accessory
12-14.	Develops compressed air	

12-15. As an ASM working on or around a unit, which of the following hazards is NOT important?
1. Tools, rags, and other foreign materials can be ingested into the air inlet of the GTC unit
2. The extremely hot and high velocity exhaust gases may strike personnel working in the area of a GTC unit
3. The high intensity sound produced by the GTC unit may impair the hearing capability of personnel in the area
4. Hot oil can be thrown from the GTC unit

Learning Objective: Indicate the function or purpose of components of GTC air, fuel, lubrication, and electrical systems.

12-16. Refer to figure 12-8 in your textbook. The compressed air that is developed for external use is obtained as bleed air from the
1. turbine exhaust
2. turbine plenum chamber
3. compressor first stage impeller
4. flame tube

12-17. Refer to figure 12-8. The compressed air used to support pneumatic loads is obtained as bleed air from the
1. flame tube
2. turbine exhaust
3. turbine plenum chamber
4. compressor first stage impeller

12-18. Constant turbine rpm is automatically maintained after the fuel system is properly adjusted. Which component of the unit is responsible for this automatic control?
1. The fuel spray nozzle
2. The turbine plenum chamber
3. The fuel and bleed air control unit
4. The flame tube inlet valve

In items 12-19 through 12-22, select from column B the fuel and bleed-air control system component that performs each function listed in column A.

	A. Functions	B. Components
12-19.	Controls fuel flow during starting and acceleration	1. Acceleration limiter valve
12-20.	Controls the rate of acceleration	2. Governor
		3. Acceleration stabilizer
12-21.	Controls the amount of air that is bled from the engine	4. Load valve
12-22.	Is closed to provide additional fuel during load operations	

12-23. Refer to figure 12-10 in your textbook. After the oil has lubricated the gears, shafts, and bearings, it is routed through the common sump directly to the
1. scavenge pump
2. oil tank
3. oil cooler
4. pressure pump

12-24. The purpose of the bypass line around the oil cooler, as illustrated in figure 12-10 of your textbook, is to

1. prevent loss of pressure in the event that the cooler becomes clogged
2. supplement the oil flow through the cooler
3. prevent cooling of the oil until the oil temperature exceeds operating temperature
4. act as a feedback line to further cool any oil that may still be too hot after leaving the cooler

12-25. The purpose of the electrical systems of the gas turbine engine is to provide the operator with the means to perform which function?

1. Operate the engine only
2. Stop the engine only
3. Start the engine only
4. Operate, start, and stop the engine

12-26. The 35 percent switch in the unit's electrical system functions to

1. deenergize the starter
2. act as a safety device
3. permit the use of bleed air
4. start the unit

12-27. The purpose of the 110 percent switch in the unit's electrical system is to

1. actuate a governor which reduces engine rpm to a safe level
2. deenergize the ignition unit if the engine rpm exceeds 110 percent
3. complete the circuit to the load light to indicate that a load may be applied
4. shut off the fuel to the engine if the engine accelerates past 110 percent

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Learning Objective: Indicate procedures for performing a preoperational inspection; and recognize operating characteristics, including starting and shutdown procedures of the GTC.

12-28. The specific gravity of the battery's electrolyte should be checked every

1. day
2. three days
3. seven days
4. thirty days

12-29. The duty cycle of the starter on the GTC engine is

1. 1 minute on, 1 minute off
2. 2 minutes on, 4 minutes off
3. 1 minute on, 4 minutes off
4. 4 minutes on, 1 minute off

12-30. When starting a newly overhauled gas turbine compressor unit, you press the oil primer button and hold it until

1. 95 percent of governed speed is reached
2. the unit lights off
3. the load light glows
4. the load is applied

12-31. You observe that the turbine discharge temperature has been 687°C for the last 7 seconds. What should you do immediately?

1. Depress the stop switch
2. Retard the throttle setting
3. Adjust the acceleration stabilizing valve
4. Disconnect the bleed-air load

12-32. The normal shutdown procedure for a gas turbine engine is to

1. disconnect and stow the air hose prior to depressing the stop switch and turning the fuel valve off
2. provide a 5 minute cooling off period before disconnecting the battery
3. turn the manual fuel shutoff valve off, and let the turbine coast down for 1 minute before depressing the stop switch
4. operate the unit at no load for 1 minute prior to depressing the stop switch

12-33. At approximately what rpm is combustion initiated?

1. 5,000 rpm
2. 15,000 rpm
3. 35,000 rpm
4. 42,000 rpm

12-34. Which of the following statements concerning the operation of the ignition system is correct?

1. A continuous spark ignition is required during running time
2. Once the engine is running normally, the ignition system is deenergized
3. The high-energy current source is obtained by discharging a booster coil into the storage capacitors
4. The high voltage required to fire the ignition plug is obtained by discharging the capacitors through a stepdown transformer

12-35. If during the start cycle the turbine temperature exceeds the specified value, what action takes place to protect the unit?
1. The acceleration control thermostat bypasses fuel, thereby reducing pressure at the fuel nozzle
2. The fuel shutoff solenoid valve is actuated, cutting off fuel to the engine
3. The ignition system is deenergized, cutting off the spark at the ignition plug
4. The starter motor relay is deenergized, preventing the engine from reaching the 35 percent point

12-36. The governor corrects an underspeed condition of the turbine by
1. increasing fuel bypass thereby decreasing the pressure applied to the fuel nozzle
2. increasing fuel bypass thereby increasing the pressure applied to the fuel nozzle
3. restricting fuel bypass thereby increasing the pressure applied to the fuel nozzle
4. restricting fuel bypass thereby decreasing the pressure applied to the fuel nozzle

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Learning Objective: Relative to gas turbine compressors, indicate the activity responsible for maintenance performance, and recognize methods of cleaning, adjusting, and testing components of the compressor.

12-37. Which activity is responsible for performing the calendar maintenance requirements on GTC units?
1. The using activity
2. The intermediate maintenance activity
3. The nearest overhaul activity
4. The local public works department

12-38. If a GTC unit develops a malfunction, the best place to obtain information concerning repairs is in the
1. Periodic Maintenance Requirement Cards
2. Maintenance Instructions Manual for the unit
3. Aviation Support Equipmentman M 3 & 2, NAVEDTRA 10315-B
4. Handbook of Operational Instructions for the unit

Refer to table 12-1 in your textbook in answering items 12-39 through 12-41. Select from column B the most probable cause of each trouble listed in column A.

	A. Troubles		B. Causes
12-39.	Excessive turbine temperature on starting	1.	Defective fuel pump governor
12-40.	Emission of smoke for a short time after starting	2.	Fuel pump acceleration control valve stuck
12-41.	Excessive oil smoke from the unit or tank vent during operation	3.	Oil cooler leak
		4.	Leaking oil pump check valve

12-42. The gas turbine engine analyzer may be used for which of the following maintenance functions?
1. Measuring exhaust temperature
2. Measuring dc and ac voltage
3. Measuring turbine unit oil and fuel pressure
4. Measuring exhaust temperature, dc and ac voltage, and turbine unit oil and fuel pressure

12-43. A reading of 2,500 rpm on the tachometer of the GTC 85 gas turbine engine analyzer represents how many rpms of the gas turbine wheel on the unit being tested?
1. 4,000
2. 9,524
3. 23,810
4. 38,096

12-44. You should always accomplish which of the following before attempting to use a gas turbine engine analyzer?
1. Calibrate the two dials on the tachometer indicator
2. Determine the currency of the required periodic calibration of the analyzing unit
3. Conduct resistance checks on the frequency meter and dc/ac voltmeters
4. Conduct a voltage check on the frequency meter

12-45. In removing hard carbon deposits you should use
1. fine sandpaper
2. soft wire brushes
3. light scraping tools
4. approved decarbonizing agents

12-46. In replacing the accessory assembly main drive gear bearing carrier seal, you must first remove the
1. governor cage and governor sleeve
2. generator and the screws and washers
3. fuel pump and fuel control unit
4. oil reservoir and pump

12-47. The fuel atomizer assembly of a gas turbine compressor unit should be cleaned by
1. soaking it in hot, soapy water and drying it in free air
2. soaking it in light oil and drying it with compressed air
3. soaking it in solvent and drying it with compressed air
4. blowing fine, oil-soaked abrasive material through the assembly

12-48. When a suitable fuel pressure gage is used to adjust the acceleration limiter valve, after the engine unit speed levels off the fuel pressure should range between
1. 46.0 and 48.0 psi
2. 44.0 and 45.0 psi
3. 39.0 and 42.0 psi
4. 35.0 and 38.0 psi

12-49. What is the minimum operating time at no-load governed speed that must be permitted prior to adjusting the acceleration stabilizer and adjustable orifice assembly?
1. 1 second
2. 30 seconds
3. 1 minute
4. 15 minutes

12-50. The starter motor clutch should have a slip-torque between
1. 90 and 100 inch-pounds
2. 100 and 110 inch-pounds
3. 110 and 120 inch-pounds
4. 120 and 130 inch-pounds

Learning Objective: Identify methods of accomplishing air conditioning and recognize terminology relating to air conditioning.

12-51. The primary purpose of air conditioning in aircraft is to
1. provide comfort for the crew
2. provide a margin of safety in case pressure suits lose their pressure
3. maintain electronic equipment to specified operating temperature
4. prevent condensation in the aircraft

12-52. The act of increasing the pressure and temperature of a substance by decreasing its volume is called
1. convection
2. compression
3. change of state
4. condensation

12-53. A three-ton air conditioner has the capacity of transferring heat at a rate of
1. 4,000 Btu per hour
2. 6,000 Btu per hour
3. 36,000 Btu per hour
4. 864,000 Btu per hour

Learning Objective: Recognize the characteristics of a refrigerant; compare advantages and disadvantages of R-12 and R-22 refrigerant; and indicate a use for R-22.

12-54. A refrigerant has which of the following properties?
1. High boiling point, absorbs and carries heat at a high temperature, and transfers heat to a cooling medium as it condenses
2. High boiling point, absorbs and carries heat at a low temperature, and transfers heat to a cooling medium as it condenses
3. Low boiling point, absorbs and carries heat at a low temperature, and transfers heat to a cooling medium as it condenses
4. Low boiling point, absorbs and carries heat at a low temperature, and retains heat after it condenses

12-55. If liquid R-12 is exposed to free air at room temperature and pressure, it will
1. decompose, forming corrosive and poisonous products
2. immediately boil
3. liberate oxygen
4. explode

12-56. What is NOT a characteristic of R-12?
1. At the low pressure point of its cycle, its pressure is slightly above atmospheric
2. It is nonexplosive, nonflammable, and of itself, nontoxic
3. It is chemically stable and essentially noncorrosive
4. It is an azeotropic refrigerant

12-57. A disadvantage common to both R-12 and R-22, which necessitates the use of a *chemical drier, is their tendency to*

1. chemically react with oxygen at high temperatures and pressures to form chlorine and flourine gases and water
2. boil at temperatures below freezing
3. absorb water
4. lose water through the expansion valve

12-58. What does a comparison of R-22 and R-12 show?

1. R-22 absorbs more water than R-12
2. R-22 has a lower boiling temperature than R-12
3. R-22 has a lower latent heat than R-12
4. R-22 has a higher boiling temperature than R-12

Learning Objective: Recognize the processes that occur during the refrigeration cycle and indicate the sequence in which they occur.

12-59. At what point in a refrigeration system is the refrigerant present as a high-pressure gas?

1. Input side of the compressor
2. Output side of the compressor
3. Output side of the condenser coil
4. Output side of the expansion valve

12-60. Refer to figure 13-1 in your textbook. The pressure in the refrigeration cycle may be referred to as suction pressure after the refrigerant passes through the

1. condenser
2. compressor
3. liquid receiver
4. evaporator

12-61. In what component of a refrigeration system does the refrigerant start changing from a high-pressure gas into a high-pressure liquid?

1. Condenser coils
2. Heat exchanger
3. Evaporator coils
4. Compressor

12-62. In a refrigeration system, the liquid refrigerant is stored in the

1. condenser coils
2. compressor
3. evaporator coils
4. receiver

12-63. High-pressure liquid refrigerant is changed into a low-pressure liquid as it *flows through the*

1. heat exchanger
2. liquid receiver
3. thermostatic expansion valve
4. compressor

12-64. The cooling of an air-conditioned space is accomplished by a stream of air which has passed over the

1. condenser coil
2. evaporator coil
3. heat exchanger
4. liquid receiver

12-65. Refer to figure 13-1 in your textbook. Which of the following is the correct flow of the refrigerant in the refrigeration cycle?

1. Evaporator coil → condenser coil → receiver → heat exchanger → expansion valve → evaporator coil → heat exchanger
2. Compressor → evaporator coil → heat exchanger → receiver → heat exchanger → expansion coil → condenser coil
3. Compressor → condenser coil → receiver → heat exchanger → expansion valve → evaporator coil → heat exchanger
4. Receiver → heat exchanger → expansion valve → condenser coil → compressor → heat exchanger → evaporator coil

Assignment 13

Air Conditioners and Preservation

Text: Pages 371 - 411

Learning Objective: Recognize the processes that occur during the refrigeration cycle and indicate the sequence in which they occur.

Refer to figure 13-1 of your textbook in answering items 13-1 through 13-5.

13-1. Heat is dissipated at the condenser coils by
1. a water vat that surrounds the coils
2. air that flows freely around the coil fins
3. air that is forced through the coil fins
4. a water jet that is directed onto the coils

13-2. The refrigerant becomes low-pressure liquid after passing through the
1. compressor
2. expansion valve
3. liquid receiver
4. evaporator coils

13-3. Cooling of the area around the evaporator coil occurs as a result of
1. liquid refrigerant changing to vapor
2. gaseous refrigerant changing to liquid
3. high-pressure liquid passing through the heat exchanger
4. low-pressure gas being compressed into high-pressure gas

13-4. The suction line of the system is the line by which
1. cold liquid enters the compressor
2. hot, low-pressure vapor enters the compressor
3. hot, high-pressure vapor enters the compressor
4. hot, high-pressure vapor leaves the compressor

13-5. The basic refrigeration cycle is considered to occur in which of the following sequences?
1. Condensation, liquid receiving, evaporation, and compression
2. Compression, expansion, evaporation, and condensation
3. Compression, condensation, expansion, and evaporation
4. Condensation, expansion, evaporation, and compression

Learning Objective: Classify the types of compressors, distinguish design features of the reciprocating compressor, and indicate the function of the compressor and condenser.

13-6. Compressors are classified according to types. Examples of this classification include which type(s)?
1. Reciprocating only
2. Rotary only
3. Centrifugal only
4. Reciprocating, rotary, and centrifugal

13-7. The reciprocating semihermetic compressor differs from the open-type compressor in that the hermetic compressor
1. maintains a larger volume of refrigerant flow
2. is driven by either a V-belt, a flexible coupling, or gears
3. is gasoline powered
4. maintains a smaller volume of refrigerant flow

13-8. Hermetic-type compressors, as used on refrigerators and freezers, can be serviced by
1. field shops only
2. the overhaul shops only
3. the manufacturer only
4. the operator

13-9. Refer to figure 13-1. What causes the high-pressure gas on the discharge side of the compressor to become liquid before reaching the liquid receiver?
1. Pressure increase by the compressor
2. Heat dissipation by the condenser
3. Heat absorption by the refrigerant
4. Pressure decrease in the evaporator

13-10. Which of the following is an air-cooled condenser?
1. Coil-and-fin
2. Shell-and-coil
3. Shell-and-tube
4. Double-tube

Learning Objective: Relative to an air-conditioning system, indicate maintenance and operating principles.

13-11. When an air conditioner is pumped down for maintenance purposes, the refrigerant receiver can entrap a volume of refrigerant equal to
1. one-third the normal charge
2. one-half the normal charge
3. two-thirds the normal charge
4. the normal charge

13-12. The type of metering device used on mobile air conditioners is a/an
1. manual expansion valve
2. automatic expansion valve
3. capillary tube
4. thermostatic expansion valve

13-13. What is the function of an expansion valve in a refrigeration system?
1. It changes high-pressure liquid refrigerant to low-pressure vapor
2. It changes low-pressure liquid refrigerant to high-pressure liquid refrigerant
3. It changes high-pressure refrigerant vapor to low-pressure refrigerant vapor
4. It changes high-pressure liquid refrigerant to low-pressure saturated vapor

13-14. In addition to its function as a constricting device, the pressure expansion valve functions to
1. prevent the high-pressure liquid refrigerant from reversing direction
2. convert the hot liquid refrigerant to a cold gas
3. convert the refrigerant gas to a liquid state
4. prevent flooding the low-pressure side of the system

13-15. Refer to figure 13-10 in your textbook. What type of energy initiates the action which causes the needle valve to open?
1. Hydraulic
2. Heat
3. Mechanical
4. Pneumatic

Learning Objective: Recognize accessory components and indicate their purposes, operating principles, and/or locations in an air-conditioning system.

13-16. Refer to figure 13-15. Why is the plunger back-seated prior to removal of the gage port plug from the service valve?
1. To block the compressor output line
2. To prevent loss of refrigerant
3. To reduce pressure in the gas lines to zero
4. To prevent passage of refrigerant from one gas line to the other

13-17. What does a cloudy or milky appearance of the refrigerant in the sight glass indicate?
1. Insufficient refrigerant
2. Hot refrigerant
3. Too-high pressure
4. Moisture in the system

13-18. In a refrigeration system, where is the king valve located?
1. On the intake side of the receiver
2. On the output side of the receiver
3. On the intake side of the evaporator
4. On the discharge side of the evaporator

13-19. The function of the heat exchanger in a refrigeration system is to
1. increase high-side pressure to prevent backup of refrigerant in the compressor
2. transfer heat from the vaporized refrigerant that is leaving the evaporator
3. transfer heat from the liquid refrigerant that is leaving the receiver
4. boil the liquid refrigerant in the condenser

13-20. Where is the drier strainer located in an air-conditioning system?
1. Between the heat exchanger and compressor
2. Between the compressor and condenser
3. Between the condenser and liquid receiver
4. Between the liquid receiver and evaporator

13-21. Where should the capillary tube bulb of a thermostat used on a mobile air conditioner be located?
1. In the cool-air outlet duct
2. Well away from any air-flow area
3. Immediately downstream of the evaporator coil
4. Where it is subjected to average conditions of the cooled space

13-22. The fusible plug provides system protection against rupture or explosion due to excessive heat by
1. stopping the compressor
2. releasing the system pressure
3. blocking refrigerant flow
4. causing continuous compressor operation

13-23. What does the control shown in figure 13-17 protect the system against?
1. Improper temperature
2. Extremes of external pressures
3. Too-high or too-low humidity conditions
4. Too-high or too-low internal pressures

Learning Objective: With respect to the NR-5C mobile air conditioner, indicate its purpose, operating principles of its components, probable malfunctions, and precautions you should observe when servicing the air conditioner.

13-24. What is the power requirement for the NR-5C air conditioner to operate the compressor motor, fan motor, and control circuits?
1. 440 vdc, 3-phase, and 60 Hz
2. 440 vac, 3-phase, and 60 Hz
3. 480 vdc, 4-phase, and 400 Hz
4. 480 vac, 4-phase, and 400 Hz

13-25. In the cooling mode of operation, the NR-5C air conditioner has a cooling capacity of
1. 22 tons
2. 24 tons
3. 30 tons
4. 40 tons

13-26. The condenser fan will cutout when the head pressure drops below
1. 140 psi
2. 145 psi
3. 150 psi
4. 155 psi

13-27. Refer to figure 13-22. The correct sequence for electrical operation in the cooling mode is
1. selector switch on, R1 closed, M1 and M2 energized, pressure switches HP and LP, R3, R4, and R5 actuated
2. selector switch on, R1 closed, pressure switches HP and LP, R3, R4, and R5 actuated, M1 and M2 coils energized
3. selector switch on, R1 open, pressure switches HP and LP closed, R3, R4, and R5 deenergized, M1 and M2 coils energized
4. selector switch on, R1 open, pressure switches HP and LP closed, R3 and R4 deenergized, R5 energized, M1 and M2 coils energized

13-28. The moisture content of the air being conditioned is lowered as the air flows through the
1. condenser coils
2. chemical driers
3. aftercool evaporator
4. precool evaporator

13-29. The air delivered to the conditioned space in the dehumidification mode is approximately
1. 30° F
2. 60° F
3. 90° F
4. 120° F

In items 13-30 through 13-33, select from column B the possible cause of each abnormal condition listed in column A.

A. Abnormal Conditions	B. Cause
13-30. Compressor fails to start	1. Air filter dirty
13-31. Suction pressure less than 40 psi	2. Hot gas bypass valve set too high
13-32. Suction pressure higher than normal	3. High- or low-pressure cutout tripped
13-33. Condenser fan will not run	4. Pressure switch open

Learning Objective: With respect to the NR-10 air conditioner, indicate its purpose, operating principles of its components, and probable malfunctions.

13-34. Which type of compressor is used in the NR-10 refrigeration system?
1. Closed-type, six cylinder
2. Open-type, six cylinder
3. Closed-type, four cylinder
4. Open-type, two cylinder

13-35. What is the heat exchange medium used in the NR-10 air conditioner?
1. R-11
2. R-12
3. R-22
4. R-500

13-36. The condensing air-flow across the condenser is provided by a
1. belt-driven, centrifugal fan
2. gear-driven, centrifugal fan
3. gear-driven, axial fan
4. belt-driven, axial fan

13-37. What type of reheat coil is utilized by the NR-10?
1. Gas-to-air
2. Liquid-to-air
3. Air-to-air
4. Electrical-to-air

13-38. The NR-10 air conditioner is composed of how many major systems?
1. Two
2. Three
3. Four
4. Five

13-39. The water solenoid valve will open to allow maximum flow during the
1. cooling mode
2. dehumidification mode
3. vent mode
4. engine starting

13-40. The solenoid dump valve and pressure switch will energize to prevent surging when conditioned air being delivered from the air conditioner is between
1. 10 to 50 pounds per minute
2. 20 to 60 pounds per minute
3. 30 to 70 pounds per minute
4. 40 to 80 pounds per minute

In items 13-41 through 13-44, select from column B the component that performs each function listed in column A.

	A. Functions		B. Components
13-41.	Meters refrigerant to the evaporator coil	1.	Evaporator coil
13-42.	Control the condensation of gaseous refrigerant	2.	Damper operators
13-43.	Returns to the compressor as a low-pressure gas through this component	3.	Expansion valves
13-44.	Cooled by low-pressure refrigerant gas from this component	4.	Pressure regulator valve

Items 13-45 through 13-51 refer to table 13-2.

13-45. The compressor starting with the selector switch in the VENT position is the result of a faulty
1. oil pressure cutout switch
2. pumpdown relay
3. hot gas bypass solenoid valve
4. compressor

13-46. If the compressor fails to start, the failure could be in the
1. damper operators
2. quench line solenoid valve
3. high/low pressure switch
4. filters

13-47. The discharge pressure gage indicates less than 168 psi. Which of the following should be done to correct this malfunction?
1. Leak test refrigerant system and add refrigerant
2. Set diesel engine to correct rpm
3. Replace the high/low pressure switch
4. Leak test refrigerant system and bleed-off refrigerant

13-48. What could be the cause of the evaporator pressure gage indicating less than 55 psi?
1. Shutoff valve closed
2. Overcharge of refrigerant
3. Defective cooling solenoid valve
4. Dirty filter or obstruction at filter guard

13-49. When the suction pressure gage indicates less than 40 psi, the fault could be in the
1. shutoff valve being closed
2. hot gas pressure regulator defective or out of adjustment
3. low oil pressure
4. pumpdown relay

13-50. If the compressor shuts down when in the COOL or DEHUM modes, the possible cause could be the result of
1. low refrigerant charge
2. low suction pressure
3. high oil pressure
4. high suction pressure

13-51. A defective high/low pressure cutout switch could cause the compressor to
1. keep on running
2. start in the VENT selection
3. increase discharge pressure to 168 psi
4. decrease discharge pressure over 168 psi

13-52. The "burn" caused by liquid refrigerant contacting the skin should be treated as
1. frostbite or frozen skin
2. a first degree burn
3. a second degree burn
4. a third degree burn

Learning Objective: Recognize how corrosion of ground support equipment can be prevented, and different classifications of preservation for the preservation of gas turbine engines.

13-53. Effective corrosion prevention is achieved only if the treated surface is free of
1. dirt only
2. moisture only
3. active corrosion only
4. dirt, moisture, and active corrosion

13-54. The type of preservative material used on ground support equipment that is not being used regularly depends upon the
1. composition of the equipment
2. availability of the preservative
3. anticipated period of idleness
4. purpose for which the equipment is used

In items 13-55 through 13-57, select from column B the classification of preservation used for each purpose listed in column A.

	A. Purposes	B. Types
13-55.	To protect engines inoperable due to missing parts or accessories, lack of test stand facilities, or internal failure	1. Type 1 2. Type 2 3. Type 3
13-56.	Openings may be closed by dust excluders or plugs	4. Type 4
13-57.	Gas turbines in non-dehydrated status require rotation with the starter or an external device at least once every 30 days	

Learning Objective: Recognize the factor that determines the preservative material used and the purposes and disadvantages of the different grades of paralketone.

In items 13-58 through 13-60, select from column B the grade of paralketone that possesses each disadvantage listed in column A.

	A. Disadvantages	B. Grades
13-58.	It is easily removed by water spray	1. Grade 1 2. Grade 2
13-59.	It is difficult to remove when old	3. Grade 3
13-60.	It may be removed by inadvertent wiping	4. Grade 4

Learning Objective: Indicate the characterisitics of corrosion-prevention petroleum and packaging and barrier materials, and the correct uses of covers and shrouds.

13-61. Which of the following statements is correct regarding the temperatures for application of class 3 corrosion-preventive petroleum?

1. It may be between 150° and 200° F for either brushing or dipping
2. It must be between 60° and 120° F for brushing and between 170° and 200° F for dipping
3. It may be applied at any ambient temperature so long as the treated surface is also at that ambient temperature
4. It must be between 60° and 120° F for brushing and between 150° and 180° F for dipping

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In items 13-62 through 13-65, select from column B the packaging and barrier material that possesses each characteristic listed in column A.

	A. Characteristics		B. Materials
13-62.	Requires special equipment for sealing	1.	Metal foil
13-63.	Has moderate water-vapor resistance	2.	Polyethylene plastic film
13-64.	Preferred as shrouding because it resists tears and punctures	3.	Polyethylene coated cloth
13-65.	Pulls loose when exposed to high humidity	4.	Tape, Fed. Spec. PPP-T-6, Type 1, Class 1

13-66. In the use of tailored dust and protective covers on ground support equipment, it would be untrue to say that the covers

1. may form a "bathtub" and trap water if improperly installed
2. may create a greenhouse effect in warm weather causing water vapor to condense on the equipment underneath
3. should be loosened or removed and the equipment ventilated in fair weather
4. should always remain on when equipment is not in use

Assignment 14

Preservation and Environmental Pollution Control

Text: Pages 412 - 433

Learning Objective: Identify the ASM's responsibilities relative to painting ground support equipment, and the materials he must use in preparing a surface for painting.

14-1. With reference to painting responsibilities, an ASM may normally be expected to
1. carry out painting projects
2. perform paint touchup jobs only
3. prepare surfaces for painting only
4. perform paint touchup jobs and prepare surfaces for painting

Items 14-2 through 14-4 refer to preparing a surface for painting. Select from column B the material to be used for each function listed in column A.

	A. Functions		B. Materials
14-2.	To prevent excessive paint buildup in areas adjacent to the treated area	1.	Pumice slurry in water
14-3.	To remove the glossy finish from the area to be treated	2.	Fresh water
		3.	Masking paper
14-4.	To remove abrasive residues from the area to be treated	4.	Mineral Spirits

Learning Objective: Recognize reasons for depreserving ground support equipment and procedures and materials used.

14-5. The amount of cleaning required after depreservation of an item of ground support equipment should be determined on the basis of
1. inspection only
2. evaluation only
3. equipment status only
4. inspection, evaluation, and equipment status

14-6. Refer to table 14-1 in your textbook. Removal of all but which of the following preservants can be accomplished with dry-cleaning solvent P-D-680 or mineral spirits TT-T-291?
1. Soft film compound
2. Plastic protective coating
3. General purpose lubricating oil
4. Corrosion preventive fingerprint remover

Learning Objective: Identify the greatest threat to the structural integrity of ground support equipment, objectives of every maintenance training program, and causes of corrosion and the most practical means of deterring it.

14-7. Structural integrity of existing ground support equipment is threatened principally by
1. high strength demands upon the metal
2. the close tolerances of safety demanded in the parts
3. the composition of the metal parts
4. metal corrosion

14-8. Which of the following should NOT be included among the objectives of every maintenance training program?
1. Developing the skills required to cope with the problems of corrosion
2. Being able to recognize the various types of corrosion
3. Understanding the dangers of corrosion
4. Use of CO_2 to prevent corrosion

14-9. Salt water causes electrochemical corrosion because it furnishes both a corrosive agent and a/an
1. chemical catalyst
2. electrical conductive path
3. chemical neutralizer
4. path of decay

14-10. Refer to figure 14-1.in your textbook. Which of the following statements is correct concerning the flow of electrons within a metal during an electrochemical attack?
1. Electrons flow from the anodic area to the cathodic area, resulting in deterioration of the latter
2. Electrons flow from the cathodic area to the anodic area, resulting in deterioration of the latter
3. Electrons flow from the anodic area to the cathodic area, resulting in deterioration of the former
4. Electrons flow from the cathodic area to the anodic area, resulting in deterioration of the former

14-11. The most practical positive means of deterring corrosion is by
1. preventive maintenance
2. keeping equipment subject to corrosion away from a corrosive environment
3. educating all hands to be able to recognize the different forms of corrosion
4. ensuring that no dissimilar metals are used in the construction of any equipment subject to a corrosive environment

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Learning Objective: Indicate typical corrosion characteristics of various common metals.

● Items 14-12 through 14-16 refer to the following metals used in aircraft support equipment construction:

A. Copper
B. Chromium
C. Aluminum
D. Nickel
E. Iron and Steel
F. Cadmium
G. Magnesium
H. Zinc

14-12. The most easily recognized type of metal corrosion occurs on
1. A
2. C
3. E
4. G

14-13. Corrosion on a structure fabricated from which of the metals listed requires prompt attention because it can penetrate the metal in a very short time?
1. G
2. F
3. D
4. B

14-14. Which of the metals listed is generally corrosion resistant?
1. H
2. F
3. B
4. A

14-15. Which of the metals listed protects by being intentionally consumed when used as a coating to protect the part to which it is applied?
1. F
2. D
3. C
4. B

14-16. Which of the metals listed actually forms a physical noncorrosive barrier over the part to which it is applied?
1. H
2. G
3. D
4. C

Learning Objective: Identify the basis for effective prevention of corrosion of ground support equipment, and recognize the types, characteristics, uses, methods of application, and precautions applicable to the various materials and methods used to prevent and remove corrosion.

14-17. Hazards associated with the use of solvents for cleaning ground support equipment do NOT include the
1. ever-present danger that they might ignite or explode
2. damaging effect they may have on the material being cleaned
3. toxic effect they may have on the user if he breathes their vapors for a prolonged period of time
4. damage to the wash pit

14-18. Which of the following solvents is used in naval aviation as a general all-purpose cleaner for metals, painted surfaces, and fabrics?
1. Safety Solvent
2. Mineral spirits
3. Stoddard Solvent
4. Methyl ethyl ketone

In items 14-19 through 14-21, select from column B the solvent used for each purpose listed in column A.

	A. Purposes	B. Solvents
14-19.	To clean acrylics	1. Methyl chloroform
14-20.	To clean primer coats before applying lacquer	2. Aromatic naphtha
14-21.	To remove grease from and to clean engine components	3. Methyl ethyl ketone
		4. Aliphatic naphtha

14-22. MIL-C-15074B designates a solvent that is used to
1. remove spots of lacquer or primer deposits
2. remove fresh fingerprints from a surface
3. clean bare metal surfaces
4. clean oil and grease from heavily soiled painted surfaces

14-23. For best results, how should cleaning compound, solvent, grease emulsifying, type I be applied to a surface?
1. By wiping
2. By brushing
3. By dipping, followed by wiping
4. By spraying, followed by brushing

14-24. Cleaning compound, solvent, grease emulsifying type II differs from the other emulsion cleaners in that it contains
1. carbolic acid
2. Stoddard Solvent
3. soap and water
4. nitric acid

Items 14-25 through 14-27 refer to emulsifying cleaners. Select from column B the cleaner that is used for each function listed in column A.

	A. Functions	B. Cleaners
14-25.	To remove chalking epoxy surfaces	1. Cleaning compound, solvent, grease emulsifying, type I
14-26.	To remove paralketones from surfaces	2. Cleaning compound, solvent, grease emulsifying, type II
14-27.	To remove atmospheric film from surfaces	3. Cleaning compound, water emulsion
		4. Cleaning coumpound, solvent, grease emulsifying, type III

14-28. If an aircraft must undergo heavy duty cleaning when the ambient temperature is 15° F, what cleaning agent should be used?
1. Stoddard Solvent
2. Pumice
3. Cleaning compound, waterless
4. Cleaning compound, water emulsion

14-29. General abrasive cleaning of aluminum surfaces should be accomplished with
1. aluminum wool
2. aluminum oxide paper
3. carborundum paper
4. lacquer rubbing compound, type III

14-30. What should be used to clean minor oxidation from a surface?
1. Silicon carbide paper
2. Lacquer rubbing compound, type III
3. Powdered pumice
4. Aluminum oxide paper

14-31. Bicarbonate of soda is a very valuable compound because it can be used to
1. clean tarnished silver contacts only
2. neutralize acid deposits only
3. clean battery holders only
4. clean tarnished silver contacts, neutralize acid deposits, and clean battery holders

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In items 14-32 through 14-34, select from column B the cleaning method that is used for each operation listed in column A.

	A. Operations	B. Methods
14-32.	To remove a majority of soils with a minimum of manhours expended	1. Water wash cleaning
14-33.	To remove oil and grease that cannot be easily removed by other methods	2. Emulsion cleaning
14-34.	To clean areas lightly contaminated with dirt and grease	3. Steam cleaning
		4. Powered buffing

14-35. Inasmuch as cleaning operations can cause a buildup of static electricity, the equipment being cleaned should
1. be grounded
2. be rinsed with clean water
3. not be cleaned with steel wool
4. not be cleaned with flammable fluid

14-36. The temperature of a metal surface should be above the dewpoint of the ambient atmosphere when preservatives are applied, otherwise condensation of moisture on the surface may occur and
1. prevent the formation of a uniformly thick coating of preservative
2. cause corrosion under the preservative
3. prevent even drying of the surface of the preservative
4. retard bonding of the preservative to the surface

14-37. For which of the following purposes are lubricants used?
1. To dissipate heat only
2. To reduce friction only
3. To prevent corrosion only
4. To dissipate heat, reduce friction, and prevent corrosion

14-38. Which of the following should be considered when selecting a lubricant to be used as a preservative on an item that is to be stored temporarily?
1. The time required to reactivate the item
2. The ability of the preservative to withstand high pressures
3. The reduction of friction between moving parts
4. The viscosity of the lubricant

In items 14-39 through 14-42, select from column B the lubricant to be used for each purpose listed in column A.

A. Purposes

14-39. For preserving equipment for 30 days or more

14-40. For displacing water in external piano-type hinges

14-41. For general purpose lubrication where low viscosity is required

14-42. For flushing hydraulic parts and components prior to their being forwarded for repair

B. Lubricants

1. MIL-H-5606A
2. MIL-L-7870
3. MIL-L-3150
4. MIL-H-6083

Learning Objective: Identify methods of protecting various metals from corrosion and of removing corrosion from selected metals, including the definition of corrosion damage limits.

14-43. Aluminum alloy coated with a thin sheet of pure aluminum is said to be
1. anodized
2. clad
3. exfoliated
4. extruded

14-44. Aluminum alloys that have a chemically produced film of aluminum oxide as a protective measure on their surfaces are said to be
1. anodized
2. clad
3. exfoliated
4. extruded

14-45. Which of the following statements applicable to the removal of corrosion from an anodized aluminum surface is correct?
1. Steel wool or steel brushes may be used to remove the corrosion
2. Chromic acid should be used to remove the protective coating adjacent to the corroded area
3. Buffing is the first step in removing the corrosion
4. Fiber bristle brushes may be used to remove the corrosion

14-46. What operation may be performed in the field when removing corrosion from stainless steel?
1. Removing of heat scales
2. Blasting at 60 psi with 100-mesh garnet
3. Wire brushing
4. Light blasting at 40 psi with 100-mesh garnet

14-47. The term referring to the amount of metal which may be removed from a corroded part without reducing its strength below a safe level is
1. normal stress limits
2. corrosion damage limits
3. tensile strength
4. limit of elasticity

Learning Objective: Identify the sources, effects, and prevention of pollution.

14-48. The contamination of the air is done usually with
1. unwanted gases, sludge, and other substances
2. unwanted gases, smoke, and other substances
3. unwanted gases, sound, and smoke
4. sludge, sound, and smoke

14-49. When were the first complaints registered against air pollution?
1. Latter part of the 19th century
2. Early part of the 19th century
3. Early part of the 20th century
4. Latter part of the 20th century

14-50. Pollution control laws were adopted by Chicago and Cincinnati as early as
1. 1891
2. 1918
3. 1781
4. 1881

14-51. Los Angeles smog is mainly due to
1. sunlight on gases emitted by car exhaust systems
2. sunlight off water
3. sunlight from the smoke of its factories
4. strong winds

14-52. How many classes of air pollution are pumped into the air?
1. Five
2. Six
3. Three
4. Four

14-53. Pollution caused by the incomplete burning of the carbon in fuels is called
1. carbon trioxide
2. carbon dioxide
3. carbon monoxide
4. sulfur oxides

14-54. Two-thirds of the carbon monoxide in the air comes from
1. steam engines
2. internal gasoline combustion engines
3 internal diesel combustion engines
4. carbon dioxide

14-55. Forty-two percent of particulate matter pollution is caused by
1. forest fires
2. stationary fuel combustion
3. industrial process
4. automobile engines

14-56. The particulate emitted from industrial sources that can cause lesions in the lung is called
1. asbestosis
2. lead
3. asbestos
4. beryllium

14-57. What fuel produces 60 percent of all sulfur oxides when burning?
1. Oil
2. Coal
3. Gasoline
4. Diesel

14-58. Why, if ever, are nitrogen oxides that automobile engines emitt so hard to control?
1. Reducing other pollutants tends to increase the output of nitrogen oxides
2. Reducing other pollutants tends to decrease the output of nitrogen oxides
3. Reducing other pollutants has no effect on the output of nitrogen oxides
4. Nitrogen oxides do not require control

14-59. When was the first Federal program dealing with air pollution created?
1. 1945
2. 1952
3. 1955
4. 1965

14-60. When were the standards established for motor vehicle pollution amended to the 1963 clean air act?
1. 1963
2. 1965
3. 1970
4. 1975

14-61. What is the purpose of the PCV valve?
1. To allow fuel vapors to flow from the intake manifold so the engine will not pollute the air
2. To allow crankcase vapors to blend with the fuel-air mixture in the combustion chamber
3. To prevent crankcase vapors from seeping into the exhaust manifold
4. To prevent crankcase vapors from seeping into the intake manifold

14-62. The air injection system installed on some automotive gas engines consists of a/an
1. air pump, air manifold, relief valve, and diverter valve
2. air pump, air manifold, check valve, and diverter valve
3. air pump, check valve, relief valve, and hydraulic motor
4. check valve, relief valve, hydraulic motor, and reverse-flow manifold

14-63. Which two categories of water pollution is the Navy mainly concerned with?
1. Eutrophication and anaerobic
2. Oil and anaerobic
3. Organic waste and anaerobic
4. Organic waste and oil

14-64. A pollution-resistant type fish is called
1. carp
2. catfish
3. bass
4. trout

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